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ABSTRACT

The objective of this document is to provide information about estuaries, the impact of uses on the environmental health of an estuary, and what communities and concerned individuals can do to manage and protect their local estuarine resources successfully. Much of the information presented here pertains to other embayments along the Maine coast that may not be true estuaries. The first of the book's three chapters describes natural features of estuaries in Maine and the importance of these special environments. The second chapter details the sources and effect of water pollution and habitat alteration on estuarine resources. The final chapter examines how land use planning can be used to protect and improve coastal water quality and natural resources. Regulatory and nonregulatory tools that promote wise stewardship of estuarine resources are reviewed. A 14-item reference list is provided. Sources for more information are summarized in the appendix. (KR)

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The Estuary Book

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The Estuary Book

A Guide to Promoting Understanding and Regional Management of Maine's Estuaries and Embayments

Maine Coastal Program
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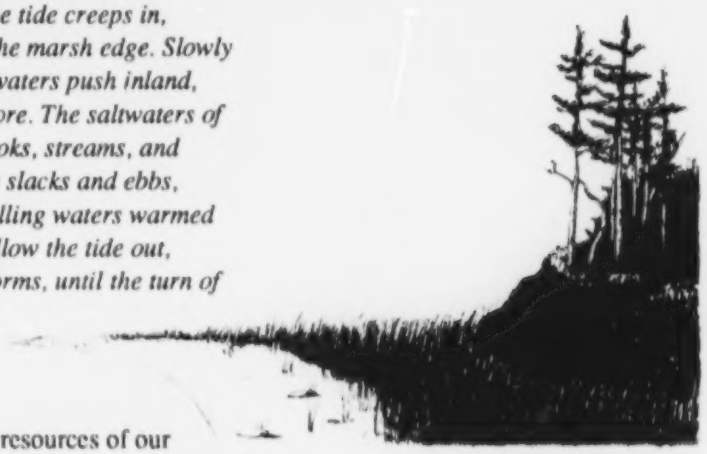
Introduction

The coast of Maine is a beautiful mosaic of estuarine environments: salt marshes and mud flats, tidal rivers and creeks, bays and coves. Twice a day the tide creeps in, rolling over mud flats and lapping at the marsh edge. Slowly the seaward current reverses and the waters push inland, over the marsh grasses to wash the shore. The saltwaters of the sea mingle with freshwaters of brooks, streams, and rivers. After the estuary is full, the tide slacks and ebbs, draining wetlands and tidal creeks, pulling waters warmed by the mud flats out to sea. Diggers follow the tide out, turning over the mud for clams and worms, until the turn of the tide brings them home.



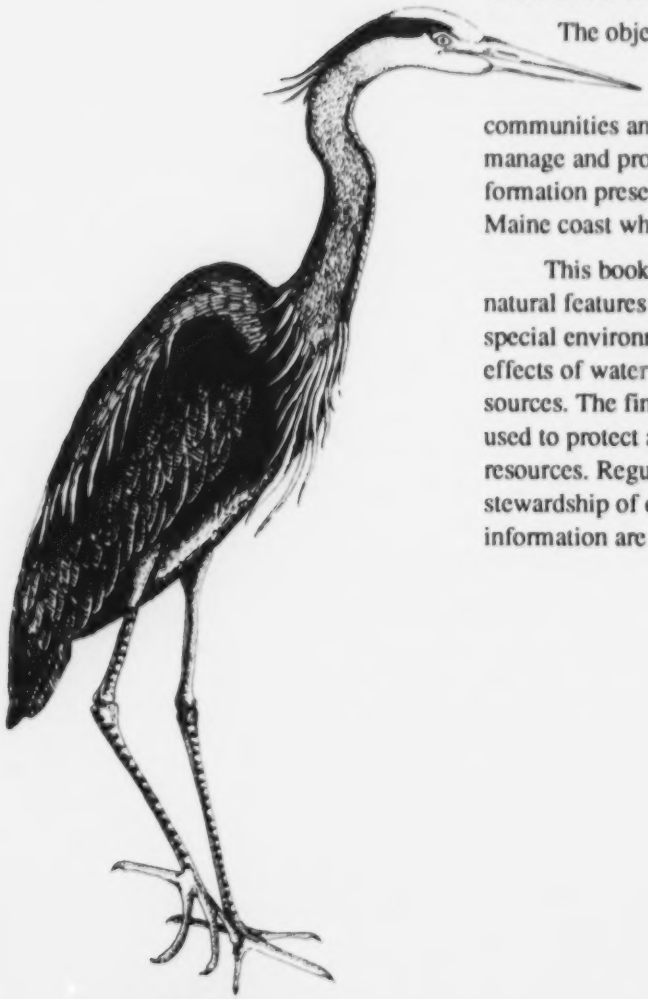
Estuaries are among the most precious resources of our coast. As productive environments where fresh and salt waters meet, estuaries provide valuable habitat for an abundance of marine life, birds, and other creatures as well as pathways to inland waters for migratory fish. The vistas of undisturbed marsh and clean tidewaters are treasured scenic resources and visually define a quality of life cherished by coastal residents and visitors to Maine.

Oyster and clam shell heaps, the last remaining traces of settlement by ancient peoples, line the banks of many Maine estuaries and attest to the long attraction of estuaries as places to live and find food. In recent times, human activities along the shores of Maine estuaries have left a more damaging legacy than decomposing shells.

For generations, coastal residents disposed of untreated sewage in estuary waters and located dumps in coastal wetlands without concern. Channels and harbors were dredged to provide safe passage and anchorages for boats and ships, and the dredge spoils placed on marshes or other sensitive sites. Industries once were allowed to discharge harmful wastewaters without treatment into Maine estuaries. The natural bounty of the Gulf of Maine has accommodated the excesses of human activities to an extent; our coastal waters remain relatively clean compared to more industrialized parts of the country.

Recently, however, signs of environmental damage have become apparent. Widespread closures of shellfish areas due to bacterial pollution, declines in fish landings, and evidence of toxic compounds in estuary and bay sediments have raised concern that our coastal waters need the same level of management and protection that we give our freshwater rivers and lakes.

The Maine Coastal Program is a cooperative effort by federal, state and local governments to manage the resources of the Maine coast, including estuaries. In December of 1989, the Maine Coastal Program initiated an Estuary Project to focus on the management needs of these productive coastal systems. While investigating the problems of Maine estuaries and developing a state strategy for estuarine management, the project identified a need for informational materials on Maine estuaries and on the environmental problems associated with estuarine resource use. Profiles describing nineteen Maine estuaries were prepared and published as the *Estuary Profile Series*. *The Estuary Book* was created to pull together basic information on estuarine systems and coastal pollution as well as to provide ideas for communities and citizens concerned with the future of our estuaries.



Great Blue Heron
(Ardea herodias)

The objective of *The Estuary Book* is to provide information about estuaries, the impact of uses on the environmental health of an estuary and what communities and concerned individuals can do to successfully manage and protect their local estuarine resources. Much of the information presented here pertains to other embayments along the Maine coast which may not be true estuaries.

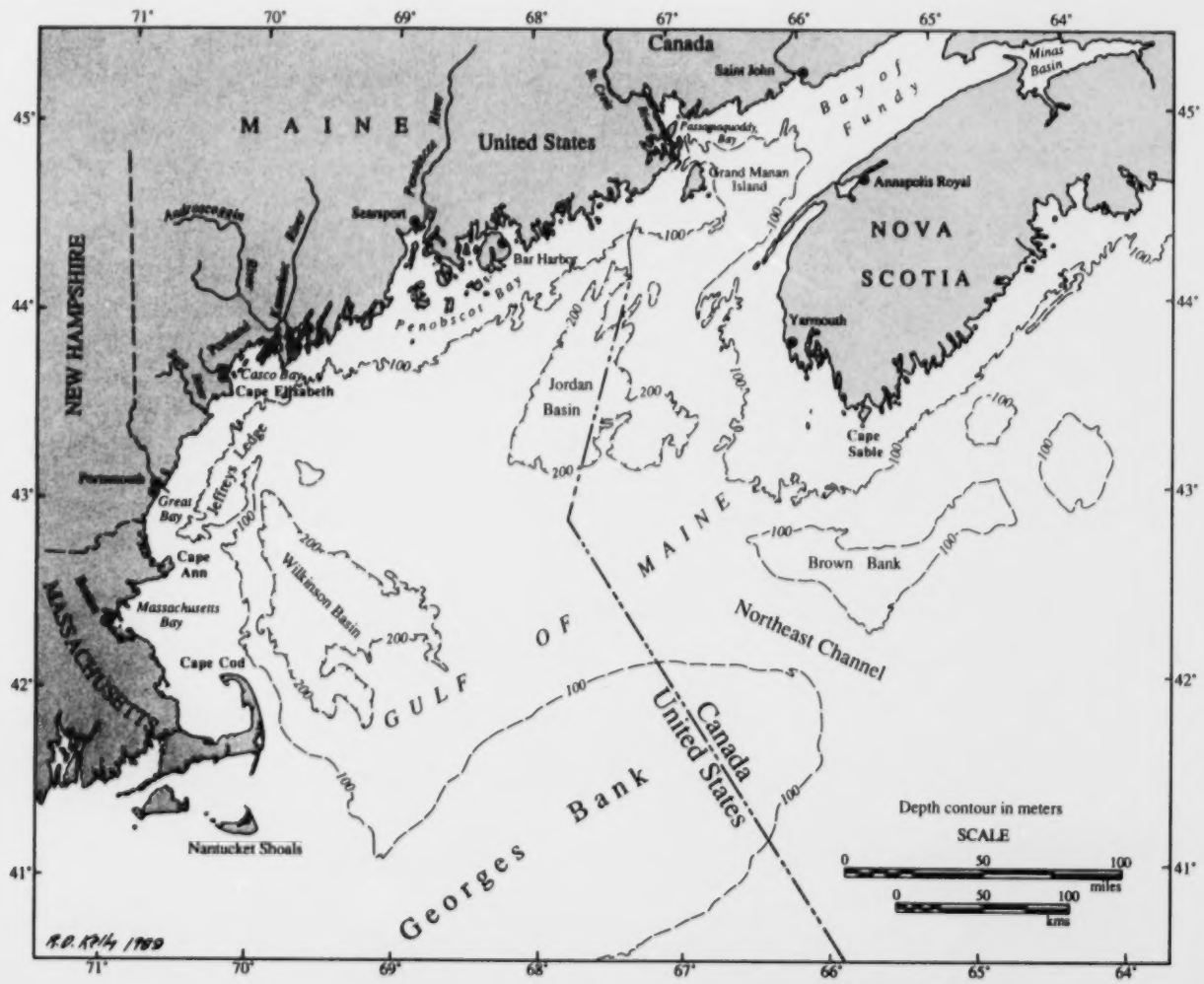
This book has three chapters. The first chapter describes natural features of estuaries in Maine and the importance of these special environments. The second chapter details the sources and effects of water pollution and habitat alteration on estuarine resources. The final chapter examines how land use planning can be used to protect and improve coastal water quality and natural resources. Regulatory and nonregulatory tools that promote wise stewardship of estuarine resources are reviewed. Sources for more information are summarized in the Appendix.

Chapter One
Maine Estuaries: Resources & Values

What is an Estuary?

"An estuary is a semi-enclosed coastal body of water which has free access to the ocean and within which seawater is measurably diluted by freshwater from land drainage" (Pritchard, 1967).

By this classic definition, the entire Gulf of Maine (see map below), limited by Cape Cod to the southwest, Georges Bank offshore and the Bay of Fundy to the northeast, may be considered an estuary since Gulf waters are somewhat isolated from the Atlantic Ocean waters by uplands and submerged banks offshore, receive a tremendous volume of freshwater run-off from land, and exchange water freely with the North Atlantic through the Northeast Channel. Moving closer to shore, a pattern of rugged headlands and islands defines bays of all sizes along the Maine coast.



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The Estuary Boundary

For the purposes of this guide, the estuary boundary includes the waters inland to the head of tide and seaward to an imaginary line drawn across the mouth of the embayment and all contiguous wetlands (fresh and salt marsh) as well as shorelands within the extreme high water mark or the 100-year flood boundary, whichever is greater.

An estuary, as defined by scientists, includes all waters measureably diluted by saltwater, which may be below the head of tide and extend far offshore beyond headlands at the mouth of the estuary.

Casco Bay and other large bays along the Maine coast have waters diluted by freshwater discharge from rivers and streams. Casco Bay, bounded by Cape Elizabeth and Small Point headlands, is often called an estuary. The salinity within Casco Bay varies slightly with changes in the amount of freshwater flowing into the bay, however, the bay is basically a marine habitat.

The Fore, Presumpscot, Cousins, and Royal Rivers are the major estuarine embayments that contribute to the estuarine character of Casco Bay. Middle and Maquoit Bays and the Harraseeket and New Meadows Rivers are embayments within Casco Bay that receive freshwater from land run-off, small streams and brooks. These coastal features are called neutral embayments because they receive low volumes of freshwater. Although not true estuaries, salt marshes, migratory fish streams, and other ecosystems associated with estuaries often fringe the edges of neutral embayments.

Estuaries are the focus of this handbook. Neutral embayments will be included since these productive coastal systems are facing similiar water quality and resource management problems. This chapter will discuss the characteristics and importance of the nearshore embayments at the interface of land and sea.

Maine Nearshore Embayments

Maine nearshore embayments fall into two very general categories: **estuaries** and **neutral embayments**. Estuaries have at least one major freshwater source that measureably dilutes the sea waters. Estuaries can have considerable freshwater inflow--the Kennebec, St. Croix, Penobscot, and Machias Rivers; or very little--the Damariscotta and Medomak Rivers. The freshwater sources of many small and medium sized river estuaries of the mid and eastern Maine coast originate in ponds or lakes, often within 40 miles from the head of tide.

In Maine, estuaries occupy coastal river valleys flooded or drowned by sea level rise. When sand and gravel are deposited by longshore and river currents across the mouth of coastal rivers or streams, bar-built estuaries are formed. The Webhannet River (Wells Harbor), Saco River, Kennebunk River, and Mousam River estuaries are examples of bar-built estuaries. Bar-built estuaries are protected by barrier beaches and are often associated with expansive marshes. Bar-built estuaries usually drain at low tide, leaving only a small channel of freshwater flowing over the flats. These bar-built systems are dynamic environments, eroding and building as sand flows between offshore deposits and beaches and sand bars.

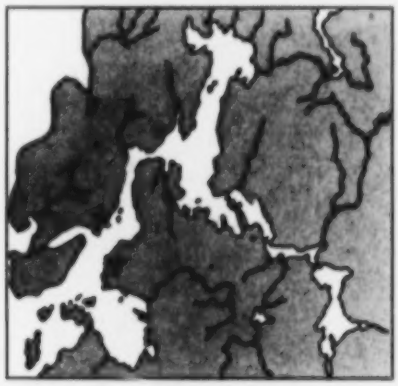
Outline of the Machias River estuary, a drowned river valley estuary.

Neutral embayments lack a major freshwater river and appear more as arms of the sea with high salinities that change very little during a tidal cycle. Neutral embayments usually have several small freshwater brooks, streams and seeps diluting the bay water. Most neutral embayments are wide and shallow, exposing expanses of productive mud flat and salt marsh at low tide. In Maine, many coastal embayments are called 'rivers', for example--the New Meadows River, Bagaduce River, Jordan River and Skillings River, when actually, they are neutral embayments with small streams and brooks providing the source of freshwater.

The narrow embayment of Somes Sound on Mt. Desert Island is considered Maine's only **fjord**. Fjords are deep estuaries created by the flooding of a glacial valley and marked by a glacial deposit or terminal moraine at the seaward limit. Although small streams feed into Somes Sound, the fjord lacks a major freshwater source.

Local indentations of the coastline are commonly called coves or inlets. Minor in size compared to other coastal features, coves are locally significant as locations for sheltered harbors. Where the embayment entrance is wide and freshwater influx minor, wave action and marine environments dominate. When the embayment entrance is restricted, freshwater flow from streams or from bordering marshlands may form an estuary. These small estuaries are important resources for coastal communities and provide valuable fish and wildlife habitat.

Outline of the Webhannet River estuary, a bar-built estuary.



Outline of the Bagaduce River, a neutral embayment.

Origins of the Present Day Coastline

The estuaries and neutral embayments of the Maine coast were created as changes in sea level flooded the coast after the last period of glaciation. Approximately 20,000 years ago, massive ice sheets moved south and east from Hudson Bay to northern New England, scouring the land bare of soil as they advanced. The rocks and soils collected in glacial deposits. Today, these deposits are mined for gravel and sand. As the earth warmed and the glaciers melted, the ocean pushed inland, flooding river valleys and lowlands.

Glaciomarine sediments were deposited in the ocean at the seaward margin of the glaciers. These fine-grained blue clays, characteristic of many Maine estuaries, are called the Presumpscot Formation. With the removal of the weight of the glaciers, the Maine coast began to rebound. Consequently, the seas retreated rapidly approximately 12,500 years ago. When the land had risen to its original elevation, the sea again began to creep inland, as a general warming trend melted glaciers around the world.

The sea continues to drown our coastline. At this time, sea level is rising at a rate of about one foot (30 cm.) a century along the Maine coast. Warming trends in global climate may accelerate this rate and sea level is projected to rise by three feet over the next one hundred years in some areas. The actual rate of sea level change varies along the coast because of local geologic conditions. In northeastern Maine and in southwestern Maine, a gradual sinking of the land contributes to variations in sea level rise (Kelley et al., 1989).

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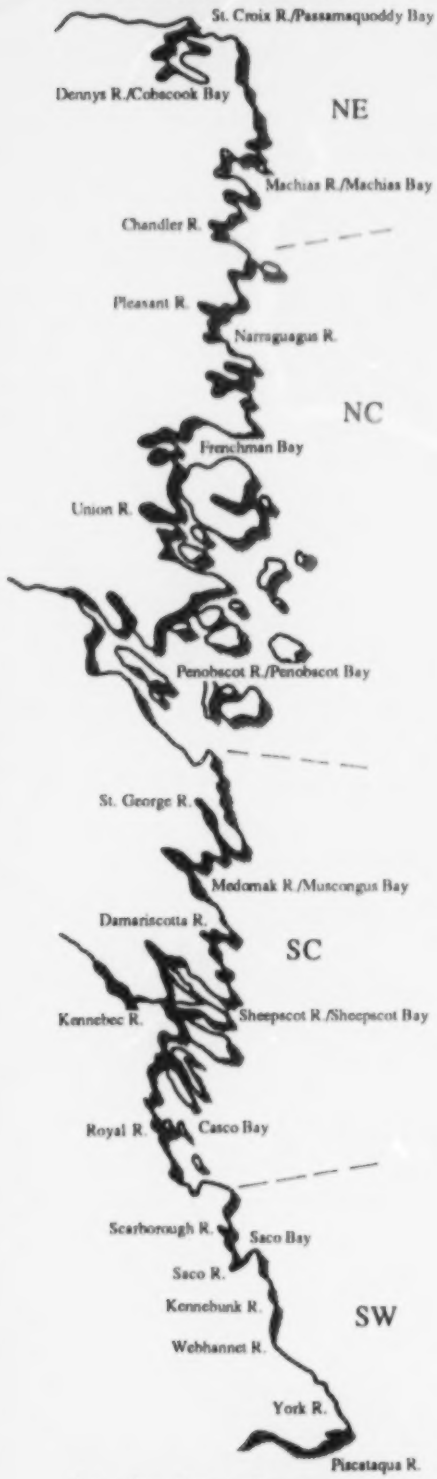
The Maine Coast



Location of coastal compartments on the Maine coast.

Each estuary and neutral embayment of the Maine coast occupies an unique setting reflecting the local geology, topography, and climate. Geologists have divided the coast into four sections or compartments that correspond to bedrock features and coastal morphology: southwest (SW), south-central (SC), north-central (NC), and northeast (NE) (after Kelley, 1987).

The southwest (SW) section extends about 42 miles from Kittery north to Cape Elizabeth. Along this section of coast, rocky capes separate arc-shaped bays bordered by sandy beaches. Old Orchard Beach on Saco Bay is the largest sand beach in this region. From the Piscataqua River north, major estuaries in this area include York River, Webhannet River (Wells Harbor), Mousam River, Kennebunk River, Saco River, Scarborough River, and Spurwink River. Many of these estuaries have broad expanses of salt marshes that are protected by sandy barrier beaches or spits.

The south-central (SC) section extends from Cape Elizabeth to Port Clyde for approximately 55 miles. This area of the mid-coast, including Casco Bay, is marked by southwest to northeast striking bedrock peninsulas separating long narrow embayments. Casco Bay is located at the southern end of this region and includes estuaries on the Fore River, Presumpscot River, Royal River, and Cousins River. The lower Kennebec River is the largest estuary in this section. Maquoit and Middle Bays and the New Meadows and Harraseeket Rivers are typical neutral embayments in this region; they are important shellfish growing areas.

To the northeast of the Kennebec River, the Sheepscot, Damariscotta, Medomak, and St. George Rivers form major estuaries characterized by productive salt marshes and mud flats. The south-central section of the coast includes a great variety of coastal landscapes and environmental conditions which permit a wide diversity of aquatic plants and animals to flourish (Adamus, 1978).

Penobscot Bay east to Machias Bay defines the north-central (NC) section of the coast, an indented shoreline with granite outcrops and many islands. The Penobscot Estuary/Bay complex is the largest along this stretch of coast. Other estuaries (from west to east) include the Passagassawakeag, Union, Narraguagus, Pleasant, Chandler, and Machias Rivers. Morgan Bay, Bagaduce River, Skillings River, Taunton Bay/Hog Bay, Mason Bay, and Little Kennebec Bay are representative of the variety and extent of neutral embayments located in this region.

The northeastern (NE) section from Machias Bay east to the Canadian border has erosion-resistant volcanic cliffs on the outer coastline (the Cutler Coast). Behind the cliffs lie well-protected estuaries at the head of Passamaquoddy Bay and Cobscook Bay. The St. Croix River estuary opens into Oak Bay/Passamaquoddy Bay along the Canadian border. To the south, the Orange River, Dennys River and Pennamaquan River estuaries form inner Cobscook Bay.

Estuary Basics

Estuaries are areas where salt and fresh waters meet. The interaction of these waters determines the currents and the distribution of plants and animals. Estuaries are complex systems with special assemblages of biological communities and environmental conditions. Estuaries share some of the same animal and plant communities as neutral embayments but the chemical and physical influence of the strong freshwater influx into the estuarine system creates conditions unique to estuaries. The following four points summarize principle characteristics of these natural systems of the Maine coast.

1. Estuaries have three subsystems - the riverine, estuarine and marine.

The boundaries of the subsystems are determined by water salinity. Salinity is a measure of the amount of dissolved salts in water. Freshwater (the riverine subsystem) generally has a salinity less than 0.5 parts per thousand (ppt) and full strength seawater (the marine subsystem) has a salinity of 30 to 35 ppt. The estuarine subsytem has varying salinities from 0.5 ppt to 30 ppt. The boundaries of each subsystem are not fixed and change with both the tide and with the seasonal floods of freshwater from snow melt and spring rains.

The Riverine

The riverine subsystem provides a pathway to inland waters for smelt, salmon, alewives, and other migratory fish which need need freshwater to spawn. In Maine, dams across many coastal rivers cut off the freshwater riverine section of the estuary and the natural upriver range of tide. In some rivers, the influence of the tide extends far inland beyond the presence of saltwater. Of the 19 miles of tidewater on the Kennebec River estuary; the upper 10 miles between Bowdoinham and Augusta is tidal freshwater.

Merrymeeting Bay is a tidal bay formed by the confluence of the Kennebec River estuary with the Androscoggin River and four smaller rivers. Merrymeeting Bay is the largest and most important tidal freshwater habitat in Maine. Many coastal creeks and rivers have tidal freshwater marshes and waters at the upper reaches of tide.

The Estuarine

In the estuarine subsystem salinities range from 0.5 to 30 parts per thousand. Animals and plants adapted to this environment can tolerate a range of salinities and temperatures. Few species can withstand the extreme fluctuations in salinity at the head of the estuary where saltwater first mixes with freshwater.

In the warmer upper reaches of a few estuaries are horseshoe crabs and other species commonly found south of cold Maine

Cat-tail *(Typha spp.)*, common plant found at the edge of fresh tidal marshes

waters. The American oyster reaches the northern natural extent of range along the U.S. coast in the upper Sheepscot River estuary.

Many species of shellfish and fish rely on the sheltered environment of estuaries and embayments as nurseries. Oceanic fish, including schools of herring and menhaden (pogies) visit estuarine waters to feed in summer months. Other fish such as the short-nose sturgeon, tom cod, nine-spined stickleback, mummichog, and species of flounder spend their entire life cycle in estuarine waters.

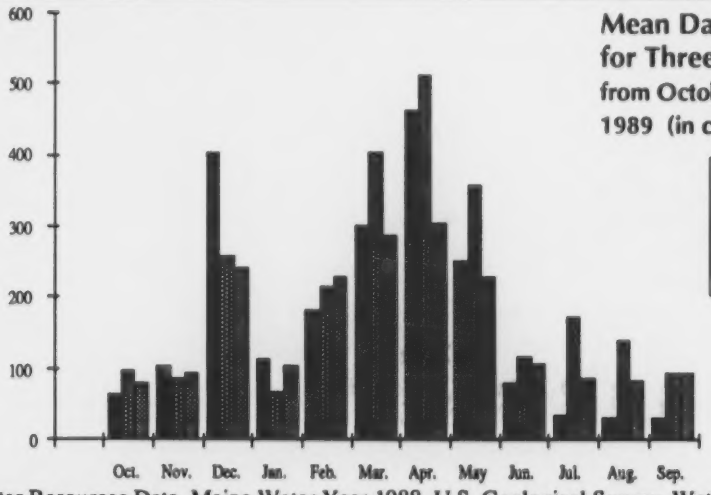
The Marine

In neutral embayments and at the seaward edge of estuaries, the marine subsystem dominates. The marine environment tends to be more stable than the other subsystems with less flux in salinity and temperature. The shores and waters resemble areas of the exposed outer coast, but are more sheltered environments. Mussel bars, kelp beds and rockweed-covered shores are features of the marine subsystem.

II. The flow of freshwater into Maine estuaries varies greatly with the season.

During the spring run-off season, from late February to May, Maine rivers normally swell from 10 to 30 times their average size. A smaller peak occurs in November or December. These seasonal variations are illustrated in the chart below. The influx of freshwater into Maine estuaries is so great during this period that it causes offshore surface waters in the Gulf of Maine to move in a huge counterclockwise spiral. The circulation gyre continues even after the spring floods end, maintained by gravity and tidal currents, and distributes rich nutrient-laden waters throughout the Gulf.

The influx of freshwater changes the distribution of salinities and circulation in Maine's estuaries. Neutral embayments may also develop salinity gradients during periods of high run-off. Marshes at the estuary edge act to soak up floodwaters, moderating the fluctuations in water flow. The flood of waters from the land also adds huge amounts of nutrients to estuarine and neutral embayment waters and triggers the algal blooms of late spring. Seasonal floods, from spring freshets and fall storms, wash tremendous amounts of silt and muds into estuaries and to a lesser extent, into neutral embayments.



Mean Daily Discharges by Month for Three Maine Coastal Rivers from October 1987 through September 1989 (in cubic feet per second).

Source: Water Resources Data, Maine Water Year 1988, U.S. Geological Survey, Water-Data Report ME 88-1.

III. Mixing between the fresh and saltwater layers and estuarine water circulation depends on the shape of the estuary, the volume of river flow, the height of tide and winds.

Freshwater is lighter than saltwater. This is why freshwater ice forms even on the saltiest coastal waters in the winter. (Freshwater also freezes at a higher temperature than saltwater.) Since saltwater is heavier than freshwater, incoming tidewaters tend to travel up the estuary along the bottom of the estuarine channel while the lighter river water flows seaward on the surface.

This two-layer circulation creates a gradient in water salinity between the bottom and surface waters and may be a seasonal feature that occurs only when the river discharge is high or in limited sections of the estuary. The same estuary in mid-summer may have very little freshwater river flow, and if tidal currents are stronger than river currents, more mixing will occur between the two layers. Winds and changes in water temperature also increase mixing between the bottom and surface waters.

The Maine estuaries receiving the greatest volume of freshwater, the Penobscot, Kennebec, and St. Croix Rivers, and some smaller estuaries including the Piscataqua, Royal, and Passagassawakeag Rivers, have long smooth salinity gradients with a two-layer circulation pattern (Larsen & Doggett, 1979).

Not all estuaries have a gradient of salinities. In some estuaries, the salinity of the estuary varies or fluctuates from fresh to salty over the course of the tide, completely mixing the water. Many shallow bar-built estuaries have fluctuating salinities. If the volume of seawater brought in by the rise in tide is much greater than the volume of freshwater flowing into the estuary basin, the salinitiy of the water will change dramatically over the tidal cycle. Aquatic life in these estuaries must adjust to extreme salinity conditions.

The Saco, Mousam, Kennebunk, Harrington, and Pleasant Rivers experience major salinity changes over a tidal cycle, from fresh to full strength seawater. The York, Sheepscot, and St. George Rivers have high ocean-like salinities at the seaward sections and fluctuating salinities in the upper sections (Larsen & Doggett, 1979).

The mixing and circulation in an estuary determines where sediments erode and accumulate as well as where pollutants collect in the estuarine basin. Information of this kind is necessary to evaluate the ecological impact of pollution discharges and dredging and harbor development projects. The circulation and salinity pattern in an estuary also influences the distribution of estuarine and marine plants and animals.

The Estuary Watershed

The estuary watershed includes all lands that drain directly to the estuary as well as all the smaller watersheds of each river, stream, and brook flowing into the estuary. Since estuary watersheds also include river watersheds, they are generally larger in area than neutral embayment watersheds.

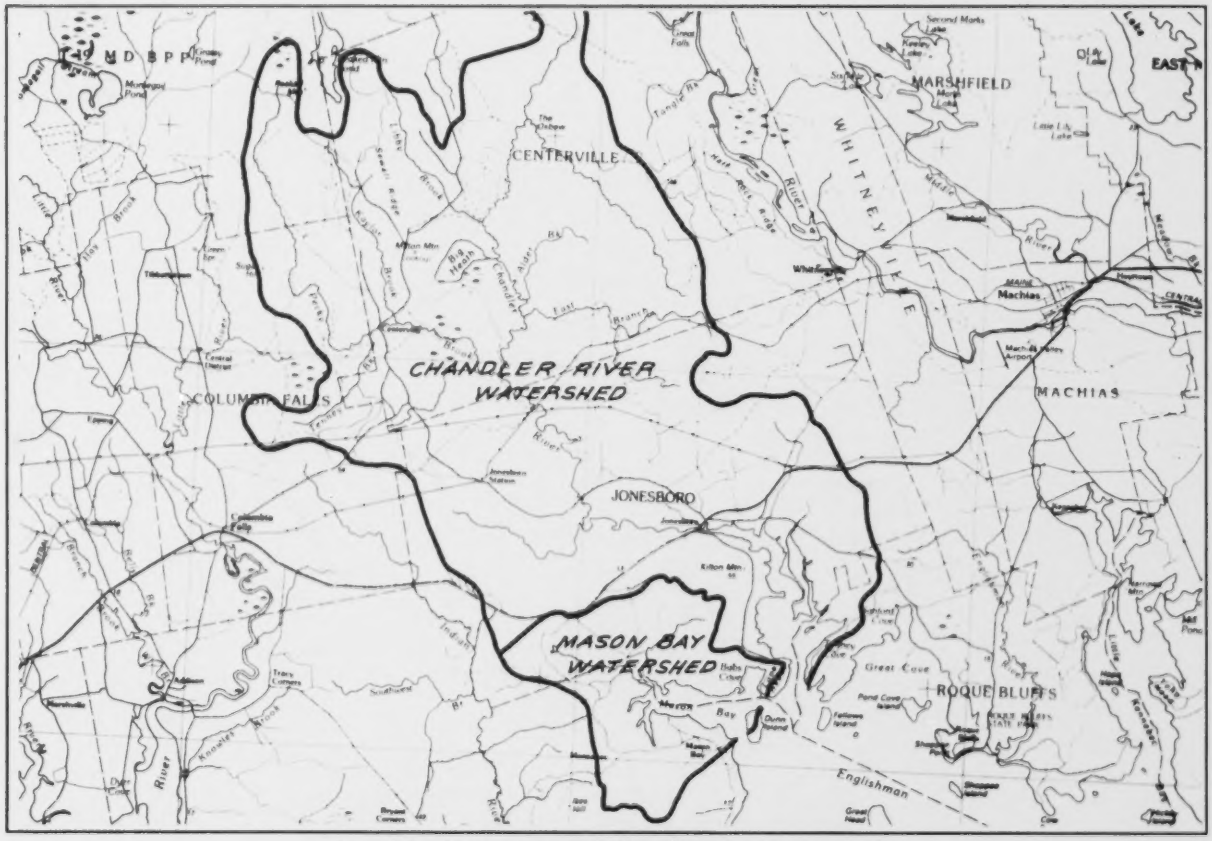
The map below outlines the watershed areas of the Chandler River estuary and the adjacent Mason Bay neutral embayment.

IV. Estuaries collect pollutants from the entire watershed.

Estuaries accumulate pollutants and sediments from discharges and land use practices upstream as well as along the estuary shores. The entire estuary watershed influences estuarine water quality.

Pollutants that enter the estuary are not washed quickly out to sea with the next tide. Many pollutants dissolve in freshwater and settle out in saltwater. The chemicals or contaminants attach to sediment particles, to each other, or to other compounds; they may sink to the bottom of the estuary, be moved by currents, dredging, or fishing activities, or be absorbed into marine plant and animal tissue.

Some pollutants remain suspended in the seawater and are eventually washed out to sea. The time it takes for all the water in an estuary to be moved out to sea is called the **flushing rate.** Flushing rates vary from days to weeks. The flushing rate of an estuary determines how long pollutants that are dissolved or suspended in estuarine water will remain in the estuary. The height of tide, size of the estuary basin, and the volume of freshwater flow determines the flushing rate. In general, the higher the tidal range, the smaller the estuary volume, and the higher the freshwater flow--the greater the volume of water exchanged during each tide.



Map of the Mason Bay and Chandler River Watersheds

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Estuarine Communities

Every living thing in an estuary has a set of environmental requirements which must be met in order to survive. These requirements--temperature, light, salinity, water, air, and soils or substrate, differ among species. Groupings of environmental factors that support assemblages of plants and animals sharing similiar requirements are called **habitats**. A **community** includes all the animals, plants and other living organisms that lives within a defined habitat.

All the living organisms within a community are interdependent. Some are predators and some prey, some depend on a certain seaweed for food or shelter, or any of a number of complex relationships. In the grand scheme of things, humans are a part of the estuarine community too. Whether harvesting food, building docks, or reseeding clam flats, the lives of coastal residents and users of the estuary are entwined with the other members of the estuarine community. Significant communities common to Maine estuaries, each representing a particular habitat, are discussed in the following section.

Coastal Marshes

Marshes are transitional areas between land and water. The salinity, frequency of flooding, and age of the marsh determines the types of plants and animals found there. Plants that tolerate fresh to slightly saline waters flourish in freshwater tidal marshes. Examples of freshwater marsh plants include cat-tails, wild rice, and arrow arum. Tidal fresh marshes are important fish and wildlife habitats. Studies indicate that of all types of wetlands, coastal freshwater tidal marshes support the greatest numbers and species of birds. Often fresh marshes fringe the landward edge of salt marshes.

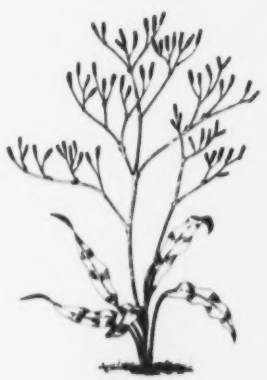
Salt meadow hay *(Spartina patens)* is a short wiry grass common to well-established high salt marshes that are irregularly flooded by high tides. Cordgrass *(Spartina alterniflora)*, a tall coarse grass of the low marsh, grows at the edge of tidal creeks and in areas with frequent tidal inundation. Cordgrass is the characteristic species of the narrow bands of marsh that fringe many Maine estuaries and bays.

Salt pannes and tidal creeks are features of Maine coastal marshes. Salt pannes are pools of tidewater that collect on top of the marsh and are home to mosquito larvae, mummichog fish and other creatures. Tidal creeks are tributaries of river estuaries and often extend far inland from the main channel of the estuary.

Marshes are important to the maintenance of a balanced coastal ecosystem. In the spring and fall, when coastal rivers swell from

Salt Meadow Grass
(Spartina patens)

Glasswort
(Salicornia spp.)



Sea Lavender
(Limonium spp.)

Plant species common to Maine's salt marshes.

One acre of salt marsh can absorb 30,000 gallons of water.

snow melt and rains, marsh grasses along rivers and tidal creeks slow the rush of waters, which allow sediment to settle and protects the shore from erosion. Spongy wetland soils absorb and gradually release waters thus moderating flood conditions and storm surges. The grasses and soils of coastal marshes trap pollutants, nutrients, and sediments from land run-off, thereby improving water quality.

Each winter ice rafts and tides break up decaying marsh grasses and wash the plant bits into estuary waters. Decaying particles of marsh grasses, algae, seaweed, and other plants are the cornerstone of the estuarine food chain and contribute to the productivity of estuarine waters. Many commercial seafood species such as lobster, herring, menhaden (pogies), alewife, crab, oyster, and clam, rely on the rich food supply of estuaries during some part of their life cycle. Small fish seek shelter in marsh grasses at high tide from Great Blue Herons and other birds that stalk the shallows to feed. Bald Eagles and Ospreys also hunt in the marshes and occasionally nest in tall trees along the estuary shore.

Intertidal Flats

Mudflats are the most common intertidal estuarine environment in Maine. The muds and sands of intertidal flats support an abundance of fauna including Baltic clams, gem clams, periwinkles, amphipods and commercially important soft-shelled clams and marine worms. Green algae mats and clumps of seaweed and blue mussels are common features of intertidal flats. Intertidal flats along the Maine coast are vital feeding and gathering grounds for much of the North American shorebird population during migrations each fall. The birds feed on tiny worms and other invertebrates that burrow in the intertidal muds, doubling their weight within two weeks in preparation for an arduous flight back to South America.

Estuary Bottom

Submerged lands of the estuary bottom support many of the same invertebrates that live on the flats and other creatures that prefer to live below the range of tide. Salinity, depth of water, and sediment type are the main factors determining the distribution of species. In more marine areas of the lower estuary, lobsters, European oysters and crabs share the bottom with other benthic dwellers. Mussels, clams, scallops, and oysters are filter feeders, filtering the estuarine waters and muds for food. Flounder, hake, cod, and other fish species also dwell near the bottom. Living in contact with the bottom muds and sands, bottom dwellers are especially susceptible to toxic pollutants that collect in the estuarine sediments.

Blue Mussels
(Mytilus edulis)

Eelgrass Meadows

Eelgrass (*Zostera marina*) meadows are important communities of the estuary bottom. Eelgrass plays an essential role in the establishment of shellfish beds and provide nursery areas for many species of fish, shellfish, and crustaceans. Neither algae nor seaweed, eelgrass is a flowering plant which blooms underwater in the spring and produces seeds in July and August.

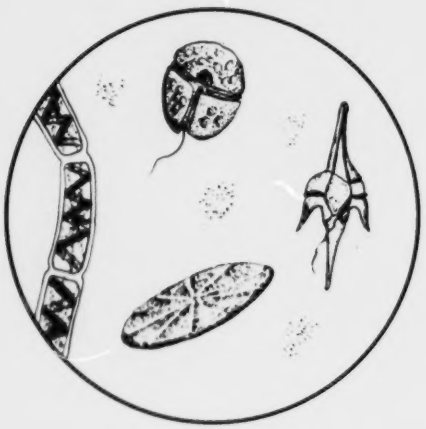
The long slender grass blades slow currents and allow suspended sediment to settle. Eelgrasses also act as nutrient buffers, taking up nutrients from the sediments and slowly releasing them when the leaves decay. Mussels and other shellfish larvae settle on the grasses to grow. Small flounder and other fish use the meadows as nursery areas. Migrating waterfowl flock to eelgrass areas to feed on the leaves and seeds. Eelgrass is a principal food source for brant geese, Canada geese and ducks.

The significance of eelgrass to coastal ecology was first recognized in the 1930s when a disease (the eelgrass wasting disease) destroyed 90 percent of eelgrass along the East Coast. During these years, bay scallop landings dropped in Massachusetts, sub-tidal areas once covered in eelgrass eroded when eelgrass beds that had anchored bottom areas disappeared, and populations of migrating American brant and other waterfowl declined.

Eelgrass has rebounded in recent years, but new threats include harbor development and sediment pollution from land run-off. Boat traffic, the harvest of shellfish and fish with heavy drags, and the dredging of navigational channels, are all activities which rip up eelgrass meadows. Outbreaks of eelgrass wasting disease have been recently reported in Maquoit and Middle Bays and the Great Bay estuary on the Piscataqua River in New Hampshire.

Run-off from lands draining into the estuary watershed can contribute heavy loads of soil, nutrients and herbicides which affect eelgrass meadows and other nearshore aquatic vegetation. Eelgrass needs light to thrive and will weaken if the water is murky with sediment or dense algal blooms for long periods. The dramatic die-off of eelgrass in Maquoit Bay and Middle Bay, has been attributed to a variety of factors including disease, mussel dragging, added nutrients and sediments from land run-off, and resuspension of sediments from boat traffic and clam digging (Short, 1988).

Eelgrass
(Zostera marina)



Plankton

Estuary Waters

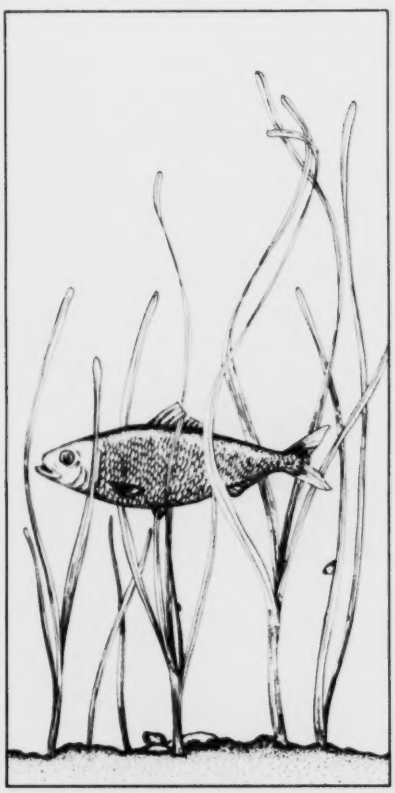
Plankton

Suspended in the waters of the estuaries are plankton. Plankton include shellfish and fish larvae, phytoplankton (one-celled plants), zooplankton (microscopic animals) and bacteria. Plankton are food for the shellfish and fish of the estuary. Seasonal floods of freshwater run-off from land each spring and late fall, bring quantities of nutrients to the estuary waters and trigger algae and phytoplankton blooms.

Red tides are blooms of a species of plankton algae toxic to humans. When red tide plankton accumulates in shellfish at toxic levels, the Maine Department of Marine Resources closes areas and prohibits shellfish harvesting to protect public health. The cause of red tide blooms is not known; nutrient-loaded run-off from land may be linked to the occurrences.

Fish

Many oceanic fish visit outer reaches of estuaries in the summer and fall to feed. The cod spawning ground at the mouth of the Sheepscot River estuary is one of the few known spawning grounds for offshore fish in Maine estuaries. Flounder are known to spawn just outside the entrance to the Webhannet River estuary and other sandy estuaries on the southern coast. Estuaries are suspected to play vital roles as nurseries for many species of fish, however, the dependence of offshore fish stocks on Maine estuaries for food, shelter, and spawning habitat is unknown.



Alewife in eelgrass.

Fish that swim from the saltwater to spawn in the freshwater are called anadromous and fish that journey from inland waters to spawn in the sea are called catadromous. Maine estuaries support one catadromous species, American eel, and eleven anadromous species--Atlantic salmon, rainbow smelt, Atlantic sturgeon, blueback herring, searun brook trout, sea lamprey, American shad, striped bass, shortnose sturgeon, alewife, and searun brown trout (introduced from Europe in the 1800s). The shortnose sturgeon is on the federal endangered species list and is found in the Kennebec, Sheepscot and Penobscot Estuaries.

We often underestimate the economic and ecologic contribution of estuarine migratory fish in Maine. Maine is unique among eastern states in the diversity and abundance of native anadromous fish. The last remaining wild runs of Atlantic sea-run salmon in the eastern United States occur in the Sheepscot, Penobscot, Narraguagus, Pleasant, Machias and Dennys Rivers each spring. Smelt, alewives and other anadromous fish are harvested commercially in many areas along the coast. The abundance of the anadromous fisheries is limited by man-made dams which block passage to spawning grounds.

The value of anadromous fish is more than the economic value of the harvest. For instance, alewives are an essential source for lobster bait in early spring before other bait becomes available. Juvenile alewives feed on zooplankton and help maintain the water quality of inland freshwater lakes. The fry are also important food for birds and larger fish. Anadromous fish, with their connections to both fresh and salt waters, epitomize the interdependence of the marine and inland environments of the coastal watershed.

Estuary waters provide ice-free habitats for loons, black ducks and other waterfowl in the winter after inland lakes freeze over. Harbor seals occasionally visit estuaries during the summer. In more remote areas, seal haul outs and bird nesting islands are found.

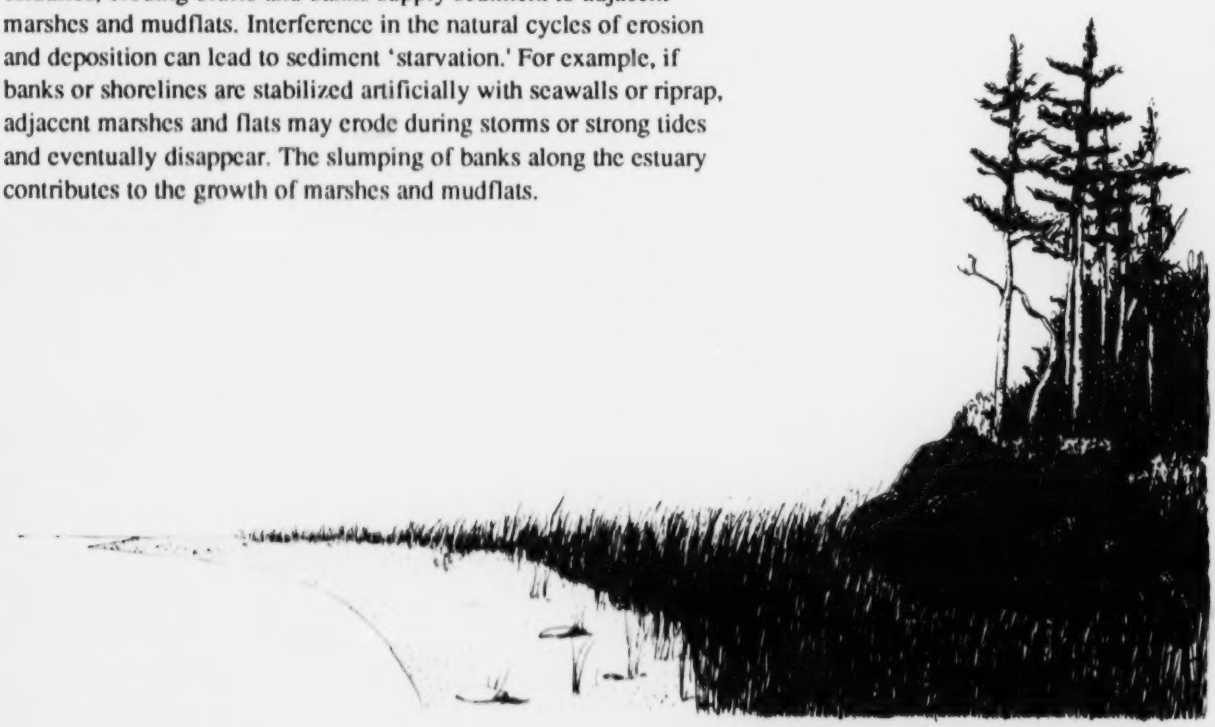
In recent years, the coastal communities of Damariscotta and Boothbay Harbor have stocked alewives in order to reduce the zooplankton population in ponds that supply the municipal drinking water systems. Large amounts of zooplankton are undesirable because they taint the water and clog filters at treatment stations.

Estuary Edges

Shorelands, Banks, Bluffs, and Beaches

The shores, banks, bluffs and uplands are vital parts of the estuarine ecosystem. The uplands and edges along the estuary buffer and sustain other habitats in the estuary. Vegetation along the edge of the estuary helps to naturally stabilize the shore and provide a buffer, filtering land run-off before it reaches the estuary waters.

In sandy estuaries, sand flows inshore and offshore, between inshore sand beaches and bars and offshore sand deposits. In muddy estuaries, eroding bluffs and banks supply sediment to adjacent marshes and mudflats. Interference in the natural cycles of erosion and deposition can lead to sediment 'starvation.' For example, if banks or shorelines are stabilized artificially with seawalls or riprap, adjacent marshes and flats may erode during storms or strong tides and eventually disappear. The slumping of banks along the estuary contributes to the growth of marshes and mudflats.



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The importance of buffers, an example--

When the Rachel Carson Wildlife Refuge was founded in southern Maine in the early 1970s, only the wetlands of Scarborough Marsh were acquired to protect habitat for migratory birds.

As residential development crept up to the edge of the marsh, the refuge managers realized that an upland buffer was essential to preserve the wildlife values of the estuarine habitats. Today, aquisition of adjacent uplands is a managemnt priority for the refuge.

Wildlife and birds use the banks and shores to gain access to the estuary edge. A number of mammals, such as shrews, otters, and raccoons, live just above the reach of tide and forage in the intertidal area. Ecologists believe these edge environments, known as **ecotones**, are key elements in maintaining the diversity and integrity of the coastal landscape.

The slow rise in sea level along the Maine coast may gradually erode soft bluffs and other edge environments. The marshes and flats may migrate inland where the lay of the land permits if bluffs and banks are available to supply sediment to these depositional systems. Coastal planners are concerned that the'hardening' of the coastline by parking lots, roads, seawalls, and other development will not allow the future expansion landward of marshes and flats flooded by rising sea level.

Recommended Reading for More Information

An Ecological Characterization of Coastal Maine. S. Fefer and P. Schettig, editors, U.S. Fish and Wildlife Service FWS/OBS-8-/29, Newton Corner, MA, 1980.

A six volume comprehensive description of Maine coast environments from Cape Elizabeth north to Passamaquoddy Bay.

"Charting Our Course",An Activity Guide for Grades 6-12 on Water Quality in the Gulf of Maine. Maine State Planning Office, Maine Coastal Program, Augusta, ME, 1989.

Available from the Maine State Planning Office.

Living with the Coast of Maine. Joseph T. Kelley, A. Kelley and O. Pilkey, Jr., sponsored by Maine Audobon, Duke University Press, Durham, NC., 1989.

This book describes the geologic processes at work shaping the coast of Maine. Coastal hazards and guidelines for safe construction on the shore are reviewed.

Secrets of a Salt Marsh. John O. Snow, Guy Gannet Publishing Co., Portland, ME, 1980.

Observations on the fauna and flora of Scarborough Marsh, Maine.

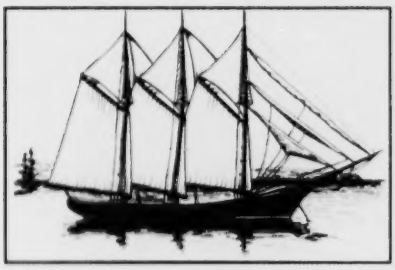
The Gulf of Maine. Spencer Appolonio, Courier of Maine Books, Rockland, ME, 1979.

A handbook on the geology and natural history of the Gulf of Maine. Available from the Courier Gazette in Rockland.

The Maine Coast--A Nature Lover's Guide. Dorcas Miller, East Woods Press, Charlotte, NC, 1979.

An introduction to coastal ecosystems and areas of interest open to the public.

Chapter Two
The Consequence of Development



Over the past twenty years, coastal Maine has experienced tremendous population growth. Some coastal towns have doubled in size; all have felt the impact of rising land values and demand for more services. As people discover the beauty and opportunities of the Maine coast, estuarine environments face stress from resource development and water pollution. This chapter explores the uses of estuaries and the impacts of human use on estuarine ecology.

Estuary Use & Pollution in Maine, a historical perspective.

In the late 1700s farmers diked and drained large salt marshes along the estuaries of the Gulf of Maine and the Bay of Fundy to create hay fields and pasture. Remnants of dikes are found in Scarborough Marsh and along the Machias River estuary. Maine salt marshes are not intensively used for agriculture today, but in some areas grasses are collected for garden mulch and seaside lavender gathered for the dried flower trade.

In the early 1800s, towns developed at the head of major Maine estuaries. Augusta, Calais and Saco were located on tidal falls which supplied energy for manufacturing. Later, dams were built to generate hydroelectric power. The rivers were used to float logs and other raw material from the interior of the state to industries along the coast. Tidewater ice, known as "white gold", was a valuable commodity shipped as far as the West Indies before the invention of refrigeration. Located at the crossroads of inland and coastal water transportation routes, Maine estuary towns such as Portland, Bath, Wiscasset, Waldoboro, Thomaston, Belfast, Ellsworth, and Machias, became centers of maritime trade and shipbuilding.

From the last half of the nineteenth century to the 1960s, manufacturers dumped industrial wastes into Maine estuaries. They assumed that pollution disposed of in coastal rivers was quickly diluted and washed out to sea. Decades of industrial discharges and other pollutants had catastrophic consequences for fish, shellfish, and other aquatic life in Maine estuaries. Wood sludge from paper mills smothered most life on the bottom of the Presumpscot, Kennebec, Penobscot, and St. Croix Estuaries before federal clean water legislation in the 1970s required pollution control measures. Shoals of sawdust linger today off the shores of historic saw mill locations in the upper Damariscotta, Machias, and St. Croix Estuaries and in other areas along the Maine coast.

One of the largest spills along the Maine coast ocurred in November 1963, when the tanker Northern Gulf ran aground on West Cod Ledge in Casco Bay. Approximately one million gallons of crude oil spilled and drifted east to strand on 400 miles of shore in the Muscongus Bay and Pemaquid Peninsula area.

Over 600,000 pounds of lobsters held in lobster pounds and over 180,000 bushels of soft-shell clams were contaminated by the oil spill (Card et al., 1981).

The Androscoggin River, which empties into Merrymeeting Bay on the Kennebec/Androscoggin Estuary, was once considered one of the nation's 10 dirtiest rivers. By 1940, sulphite-process pulp and paper mills discharged hundreds of tons of black wastewater in to the Androscoggin River each day. Thousands of fish died and dissolved oxygen levels dropped to near zero in the river and Merrymeeting Bay. In the summer of 1941 hydrogen sulfide gas from the foul river peeled paint off houses in Lewiston and sent noxious odors from Berlin, New Hampshire to Brunswick, Maine. The public outcry that ensued galvanized the cleanup of the Androscoggin and focused attention on the pollution problems of Maine rivers.

During the past forty years, five major oil spills (100,000 gallons or more) and approximately 23 large oil spills (1,000 gallons or more), have leaked from tankers, pipelines, and terminals on the Maine coast. Oil spills have damaged intertidal flats and contaminated sediments in the Piscataqua River estuary, Casco Bay, Muscongus Bay, Penobscot Bay, and Long Cove in Searsport.

Estuary Use & Pollution Today

Water quality has certainly improved in recent years, yet threats to the environmental health of Maine's estuaries have not disappeared. Industrial wastewater discharges are cleaner and more regulated than in the past and many towns have constructed municipal treatment plants to handle residential wastewater. Although Maine salt marshes are no longer ditched and drained to control mosquitos or create farmland as in the past, present day highway and bridge construction projects often damage estuarine habitats by altering marshlands or estuarine drainage.

The evidence of environmental damage in Maine estuaries of concern now is subtle and usually not as obvious as oil-soaked seabirds or clouds of foul gasses. Toxic compounds that contaminate estuarine sediment, water, and living resources are detected only through complicated analysis and the harmful effects are difficult to pinpoint.

The burgeoning coastal population has concentrated development along the uplands of Maine estuaries, increased the volume of municipal wastewater discharged into coastal rivers, strengthened demand for seafood and other marine resources, crowded harbors with recreational boats, and in general, intensified the use of these fragile ecosystems. This intensified use influences the environmental health of Maine estuaries.

The chart on the opposite page briefly describes some of the consequences of human activities on the estuarine ecosystem. The activities are grouped into four broad categories of human uses of estuarine resources and uplands--waste disposal, marina and port development, food source, and land use.

The Effect of Development on Estuarine Ecology

Waste Disposal

Manufacturing (paper & textile mills, tanneries etc.): Even when regulated and treated, wastestreams can include heavy metals (mercury,copper, lead, arsenic...), polynuclear aromatic hydrocarbons (PAHs); dioxin, and organic sludge.

Power Plants: Cooling water from power plants adds heat to estuary waters. Nuclear power plants contribute low levels of radionuclides to the estuarine environment from liquid discharges to estuary waters.

Municipal Sewage: Treatment plants discharge treated wastewater containing bacteria, nutrients, road residues, household toxics, chlorine, heavy metals and other substances including wastes from commercial businesses tied into the sewage system.

Storm Outfalls: Combined sewer overflows (CSO) and storm drain outfalls add road residues, sediment, bacteria, and trash to estuary waters. If a municipal sewage plant malfunctions or is flooded by storm waters, raw sewage may be discharged into the estuary.

Overboard Discharges: Some residential wastewater is treated with sand filtration and chlorination before disposal into tidal waters as an overboard discharge. Over 3,000 of these overboard discharges remain on the Maine Coast and add bacteria, chlorine, and nutrients to coastal waters. New overboard discharges are forbidden by state law. An unknown number of illegal straight pipes discharge sewage directly into Maine tidewaters.

Marina & Port Development

Dredging and Dredge Spoil Disposal: Dredging to maintain navigational channels or anchorages and disposal of dredge spoils results in redistribution of pollutants in bottom sediments, increased turbidity of estuarine waters and destruction of bottom habitats.

Harbor, Port and Marina Development: Boat traffic may add bacteria, chlorine, and formaldehyde from marine toilets to nearshore waters, as well as marine trash, small oil and fuel spills, and toxic bottom paints and chemicals from boat and ship maintenance activities. Boat traffic can potentially harm submerged aquatic vegetation, introduce foreign plants and animals, and cause noise pollution.

Food Source

Traditional Fisheries: A by-product of fishing is the addition of lost traps, nets and other gear as well as trash into nearshore waters. Harvesting techniques such as bottom-dragging disturbs natural estuarine bottom habitats. The repeated digging of mud flats for clams and worms changes the texture of the intertidal mudflat habitat and increases turbidity of tidal waters. Selective harvesting of particular species may change natural cycles of abundance.

Aquaculture: The feeding and raising of fish in aquaculture pens adds nutrients to estuarine waters and may alter the natural ecology under the pens. Introduction of non-native shellfish seed and fish smolt to Maine waters may unintentionally spread foreign species and diseases.

Land Use

Roads: Road run-off contains polynuclear aromatic hydrocarbons (PAHs), lead, zinc, and oil from automotive traffic as well as nutrients and bacteria from land drainage. Road construction across estuaries or tidal creeks can alter tidal flow, destroy wetland habitats and block passage for migratory fish.

Residential Development: Waterfront residential development often involves shoreline alteration with stabilization measures or dock construction. Lawn and garden fertilizers, pesticides, animal wastes, and nutrients and bacteria from malfunctioning septic systems, are all associated with run-off from residential areas. Clearing and paving land for lawns, driveways, parking lots, and roadways increases the rate of flow and volume of land run-off into coastal waters.

Agriculture: Runoff from agricultural lands often contains nutrients from fertilizers or animal manure, pesticides, and eroded topsoil.

Mining: Drainage from mining operations may include heavy metals and eroded soil.

Forestry Practices: Forestry operations involving large clearcuts or the use of skidders on slopes and streams within a coastal watershed may increase erosion of topsoil and the volume of surface water run-off. These practices increase sediment loads and water temperature in freshwater tributaries of estuaries and coastal waters. Timber management with herbicides within the estuary watershed may result in the accumulation of toxic herbicide residues in estuarine waters and sediments.

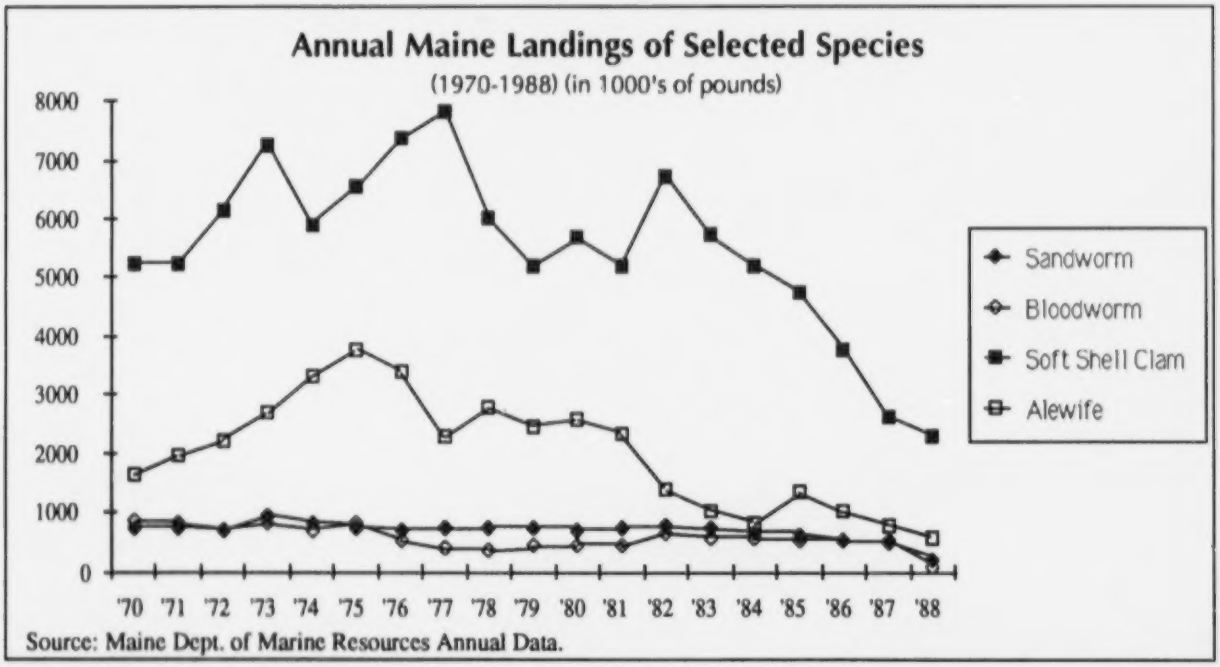
The Impact of Human Use on Natural Resources

Among the natural resources of an estuary are living resources (marine life and wildlife), estuarine habitats and communities (marshes, mudflats, and eelgrass meadows), and geologic features (sand beaches, bluffs, gravel deposits). Human impact on the natural resources of an estuary may be minor, such as the placing of a mooring or major, such as dredging to improve navigation.

Often small alterations to the estuarine shoreline appear to effect only the immediate area. These minor changes may add together over time to slowly change the ecology of an estuary and the character of the estuarine landscape. Common changes to the estuarine landscape over one year may include construction of several small private docks, new placement of moorings, removal of trees and brush from shorefront lots, or the development of a waterfront residential subdivision. The total effect of incremental changes over a period of time is referred to as **cumulative impact.**

Shoreland development changes natural rates of erosion and alters sediment supply to nearby marshes, mudflats, and beaches. Construction of wharves, docks and seawalls, riprapping shorefront and clearing natural shoreline vegetation are activities which may modify the natural processes of erosion and deposition in the estuarine environment. Dredging operations are necessary to maintain harbors and anchorages, but the removal of bottom sediment may cause variations in erosion and deposition at the dredge site and and other areas of the estuary.

Over time, enough incremental changes to estuarine habitats will significantly alter the natural estuarine ecology. Because the changes are gradual and over time, clear cause and effect relationships are difficult to determine. Commercial harvests of shellfish, fish, and worms in Maine estuaries and neutral embayments have declined over the years (see graph below). Many fish species, once harvested from Maine estuaries and harbors, are now rare. Years ago, sturgeon were fished from the Mousam River estuary and cod from the Scarborough River estuary. The precise cause of changes in the abundance and location of species is not always obvious. Habitat alteration, overfishing, water pollution, natural cycles of abundance, and climatic change all may influence the decline in landings of species that are harvested in Maine estuaries and neutral embayments.



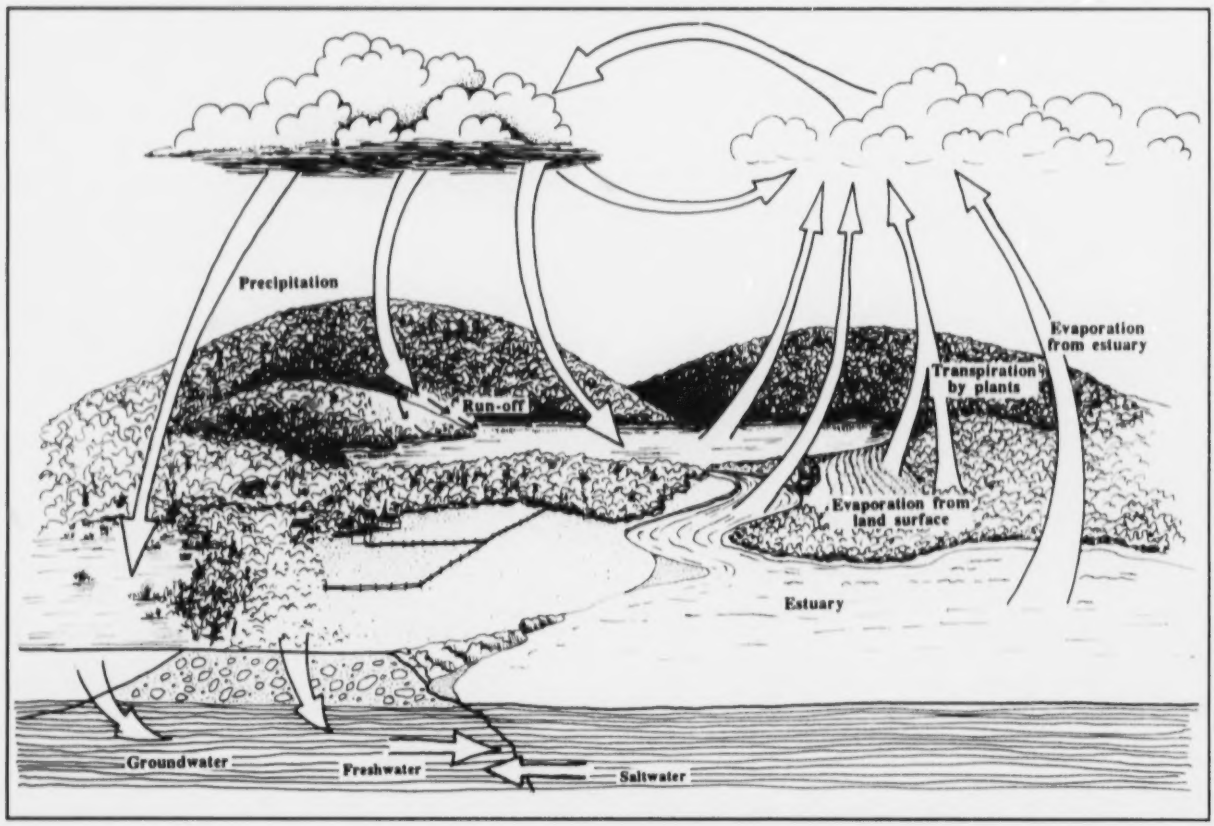
Source: Maine Dept. of Marine Resources Annual Data.

The Impact of Human Use on Water Quality

Good water quality sustains life. At the heart of estuary planning is a concern for water quality. Water quality affects fish, shellfish, and other natural resources as well as the available uses of the estuary by people. Protection of water quality within the estuary watershed includes protection of freshwater resources used for drinking, farming, recreation, and manufacturing and saltwater resources used for aquaculture, recreation, and fishing. The connections between land and water uses are strong, particularly for **water dependent** uses. Water dependent uses include activities which require access to saltwater. Marinas, fishing piers, fish packing plants, boat yards, and shellfish hatcheries are examples of developments which need or prefer a shoreside location. The development and use of shorelands directly influences nearshore water quality.

The Hydrologic Cycle

The water quality of an estuary is affected by all the uses of the land and water in the estuary watershed. Water cycles through the environment. Water falls as rain or snow, runs from rivulets to streams to rivers to the ocean, sinks through the ground to replenish groundwater, or is drawn up to sustain plants and animals. Water vapor escaping as evaporation from lakes, ocean, and land, and as transpiration from plants, forms clouds. The clouds condense, the water falls as rain or snow and the cycle begins again. These movements (illustrated in the drawing below) are called the hydrologic cycle. The hydrologic cycle demonstrates how all water in the environment is interrelated, whether it be freshwater, saltwater, or groundwater. Human use of the land and waters influences the amount and type of soil, chemicals and other pollutants carried into rivers and estuaries.



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Estuarine Pollution

Pollutants discharged directly from pipes into rivers and estuaries are called **point sources** of pollution. Point sources of pollution include all licensed discharges with federal NPDES (National Permit & Discharge Elimination System) and state discharge permits from industries, small companies, municipal sewer systems, aquaculture fish pens, and overboard discharges. Oil spills from tankers are also considered point source discharges. Some point sources, such as straight pipes discharging untreated residential sewage, are often overlooked and unlicensed. The Maine Department of Marine Resources is surveying these illegal systems.

Non-point source pollution (NPS) refers to any pollution which is not a licensed discharge or does not have a localized or clearly identified source. Non-point source pollution is associated with land and water use and poses a serious threat to coastal water quality and estuarine ecology. The non-point source label is a misnomer, since every pollutant has a source, however, the source of NPS pollution is usually not as specific as point source pollution. Inadequate septic systems, stormwater run-off, clearcutting, construction, and boat pollution all contribute to non-point source pollution along the Maine coast.

For more information on non-point source pollution contact:
Non-Point Source Pollution Program, Maine Dept. of Environmental Protection, State House Station 17, Augusta, Maine 04333.

Urban development, agriculture, and forestry operations are the major categories of land-based non-point source pollution in Maine. Each activity influences coastal water quality because of alteration of the land and removal of natural vegetation. Urban NPS pollution includes stormwater run-off (nutrients, road oils, lead, sediments) and pollution associated with residential development. Drainage from agricultural lands may include nutrients from fertilizers and farm animals, pesticides, and soil. Large clearcuts and other forestry practices may increase temperature and turbidity of streams and creeks in the estuary watershed as well as add herbicides to estuarine waters. Intensified use of estuarine waters creates water-based NPS pollution. Marinas, harbor dredging projects and finfish aquaculture operations are examples of water-based activities that can impair estuarine water quality and natural resources if not planned correctly.

The Groundwater - Estuary Connection

Groundwater seeps into estuary water and estuary water percolates into veins of groundwater. The intrusion of saltwater into freshwater municipal and private wells is a common problem along the Maine coast. Some coastal communities are served by public drinking water systems that tap surface waters (ponds, rivers, or lakes), groundwater wells, or a combination of sources. Rural residents usually draw drinking water from individual wells. In areas of the coast, increased demand on groundwater resources for residential use pulls more water from the water table than the aquifer can replenish and saltwater is drawn in to compensate. Groundwater polluted by leaking underground fuel tanks, abandoned dumps, or failing septic systems, may seep into estuaries and pollute coastal waters.

Water Classification

The Maine Department of Environmental Protection manages estuarine and marine waters by designating allowable uses and levels of pollution with a water classification system. Estuarine and marine waters are classified as SA, SB, or SC. Every three years the classification is updated and public hearings are held to review the proposed classification. During the public hearings, communities have the opportunity to comment on the water classification. The classification is based on bacteria, aquatic life, and dissolved oxygen standards.

Class SA waters are the highest classification. All discharges are prohibited in Class SA waters. Class SA waters have high quality water, unique ecological resources and are often located next to coastal parks or other public lands. The estuarine and marine communities, and dissolved oxygen and bacteria content of SA waters must be as naturally occurs.

"Class SA waters shall be of such quality that they are suitable for the designated uses of recreation in and on the water, fishing, aquaculture, propagation and harvesting of shellfish and navigation and as habitat for fish and other estuarine and marine life."

Class SB waters allow discharges which do not cause detrimental changes to the aquatic community, including finfish aquaculture and hydroelectric power generation. Most estuaries in Maine are currently designated SB. Class SB waters must have a dissolved oyxgen content at least 85% of saturation and bacteria concentration may not exceed levels recommended for shellfish growing areas. Enterococcus bacteria must not exceed specified levels between May 15th and September 30th.

"Class SB waters shall be of such quality that they are suitable for the designated uses of recreation in and on the water, fishing, aquaculture, propagation and harvesting of shellfish, industrial processing, and cooling water supply, hydroelectric power generation and navigation and as habitat for fish and other estuarine and marine life."

Class SC waters allow heavy industrial discharges as long as the water quality supports the fish and aquatic communities normally found in the area and allows swimming and fishing. The Penobscot Estuary, Portland Harbor, St. Croix Estuary and other industrialized coastal waters are classified as SC. Class SC waters must have an oxygen content of at least 75% of saturation and bacteria concentration may not exceed levels recommended for restricted shellfish growing areas. Enterococcus bacteria must not exceed specified levels between May 15th and September 30th.

"Class SC waters shall be of such quality that they are suitable for the designated uses of recreation in and on the water, fishing, aquaculture, propagation and restricted harvesting of shellfish, industrial processing and cooling water supply, hydroelectric power generation and navigation and as habitat for fish and other estuarine and marine life."

From: Water Classification Program, January 1989. Maine Revised Statutes Annotated Title 38, Article 4-A, Department of Environmental Protection, Bureau of Water Quality Control, Augusta, ME.

Dissolved Oxygen

Dissolved oxygen in the water is essential for all plants and animals living in an estuary. The amount of dissolved oxygen in water is used as an indicator of water quality and the level of life that the water can support. The maximum amount of dissolved oxygen (the saturation level) that can be dissolved in a given amount of water varies with the salinity and temperature of the water. The colder the water, the higher the saturation level of dissolved oxygen, and the more saline the water, the lower the saturation level.

The surface water in an estuary is usually at or near oxygen saturation, while conditions near the bottom vary with the amount of verticle mixing in the water column, the presence of plants such as eelgrass and seaweeds, and the demand for oxygen by shellfish, decomposing bacteria, fish, and other creatures.

Coastal Water Pollutants

Approximately one-third of the productive shellfish flats in Maine were closed in 1990 because of possible bacterial pollution.

This section explores the effects of major water pollutant categories on estuarine ecosystems.

Bacteria

Bacterial pollution from sewage treatment plants, boaters, malfunctioning septic systems, urban and agricultural run-off or household overboard discharges is usually a condition that disappears once the source of bacteria is eliminated and does not permanently harm the estuarine environment. Bacterial pollution is a human health concern which reduces the availability of shellfish for harvesting and waters for recreational activities. Malfunctioning septic systems from residences along the shore are suspected of being a major source of bacterial pollution to Maine estuaries. The Maine Department of Marine Resources (MDMR) monitors bacteria levels in shellfish growing areas as part of the Shellfish Sanitation Program in order to protect public health.

Chlorine

A serious environmental consequence of sewage discharges from municipal treatment plants, licensed overboard discharges, and marine toilets is the trace of chlorine added to kill harmful viruses and other pathogens. Chlorine is used as an antifoulant for industrial intakes at power stations and to wash down boats. Chlorination can produce very hazardous chlorinated organic compounds such as dioxin. Chlorine is also highly toxic to aquatic life in minute quantities. Traces of chlorine in estuary waters reduces and may deter migratory fish runs. The Maine Department of Environmental Protection (MDEP) requires most coastal municipal and industrial treatment systems to dechlorinate chlorinated effluent or use alternative forms of disinfection.

Nutrients

Nutrients, in particular phosphorus and nitrogen, are necessary for the overall productivity of estuarine waters. Nitrogen is usually, although not always, the nutrient limiting phytoplankton growth in Maine estuaries, just as phosphorus limits growth in most freshwater lakes. Nutrients are a concern when excess amounts produce undesirable changes in the abundance of phytoplankton and other aquatic species.

Population density and land use changes in the estuarine watershed can increase nutrient loads to estuarine waters. Wastewater sewage treatment plants, urban run-off, and agricultural activities are major land-based sources for nitogen and phosphorus in Maine estuaries. Finfish farming operations also add nitrogen from fish waste

and excess feed and can create water quality problems in estuaries that are not well flushed.

The addition of nitrogen to nearshore waters from septic systems, sewage plants, fish pens, marine heads, or land run-off can cause nuisance blooms and upset the natural balance of nutrients. Red tides are common nuisance blooms along the Maine coast each summer. Occurrences of red tides are phenomena not yet understood and may be linked to iron as well as nitrogen availability.

The loading of nutrients into nearshore embayment waters can lead to a condition known as eutrophication. Excessive amounts of nutrients cause phytoplankton to multiply or bloom in great quantities. When the phytoplankton sink and die, bacteria decompose the plankton and deplete the dissolved oxygen in the estuary. If dissolved oxygen levels become too low, shellfish and other bottom dwellers may die. A massive shellfish kill in Maquoit Bay in the fall of 1988 was caused by an unusual bloom of phytoplankton that settled to the bottom and within 48 hours had smothered 80% of the soft-shelled clams, European oysters, and other shellfish in the bay.

The one-cell microscopic algae that produces red tide*(Gonyaulax tamarensis)*. Drawing is many times actual size.

In addition to nutrients, the availability of light, iron, water temperature, and other chemical and physical factors limit the growth of phytoplankton in estuaries.

Heavy Metals

Mercury, cadmium, chromium, copper, zinc, and lead are a few of the heavy metals found in industrial discharges in Maine. Trace metals also enter the marine environment from municipal sewage treatment discharges and road run-off. Since metals tend to accumulate in marine and estuarine sediments, bottom dwelling animals including shellfish and ground fish, are most at risk. Human health is also affected by exposure to heavy metals.

High concentrations of heavy metals may naturally occur in estuarine waters because of the geology within the watershed or result from industrial discharges and urban run-off. Elevated levels of heavy metals have been detected by Maine state and university scientists in sediments in Casco Bay, Boothbay Harbor, Muscongus Bay, St. George River, Blue Hill Bay, Penobscot Bay, Union River, Narraguagus River and the St. Croix River.

Although the entire coast has not been sampled intensively, studies indicate that areas with a legacy of industrial discharges, coastal mining, or harbor activities, have some heavy metal contamination. In Boothbay Harbor, non-point source stormwater run-off from parking lots, boatyards, and marinas is suspected to be the source of high lead levels found in harbor sediments. Mine drainage from the Callahan Mine on the shore of Cape Rosier in Blue Hill Bay has caused local shellfish to accumulate unnaturally high levels of copper.

Petroleum Derivatives

Polynuclear aromatic hydrocarbons (PAHs) and other aromatic compounds are major concerns because of their mutagenic (change cell growth) and carcinogenic (cause cancer) properties. Sources of PAHs include oil from tanker spills, bilge water discharges, leaking underground gas storage tanks, discarded motor oil bottles, road run-off, sewage plants, rainfall, and creosote from wharf pilings.

The presence of PAHs and other organic petroleum compounds can be predicted in areas of past oil spills, intense harbor activity, and municipal and industrial discharges. The discovery of PAH levels in Casco Bay higher than those found in Boston Harbor heightened a growing awareness that the marine environment in Maine is not as pristine as once believed (Larsen et al, 1983). Low levels of PAHs have also been found in sediments of Penobscot, Machias and Frenchmen Bays.

Organochlorines and Other Synthetic Organic Compounds

The bald eagle population, once threatened by the effect of DDT on chick survival, has rebounded in Maine. Canadian studies of marine mammals, however, reveal that DDT still persists as an environmental problem.

Organochlorines are stable compounds that accumulate in sediment and the fatty tissues of animals. Organochlorides (DDT), polychlorinated biphenyls (PCBs), and dioxin are highly persistent in the environment and harmful to animals. PCBs were once used in electrical equipment and have not been manufactured in the U.S. for over ten years, yet they continue to enter the environment from improper disposal or leaking shoreside landfills. Low levels of PCBs in mussel tissue have been recorded by EPA in Casco Bay, Penobscot Bay, Machias Bay, and Frenchman Bay.

The presence of DDT and PCBs is not as predictable as that of other pollutants. Dioxin, however, is associated with a certain kind of paper mill discharge. Dioxin is a by-product of the kraft paper-making process which bleaches wood pulp with chlorine. The lignins (natural binders of wood fiber) from the wood and the chlorine combine to produce dioxin, a substance suspected to cause birth defects in humans. In March 1990, the Department of Environmental Protection released the results of a study which revealed the presence of dioxin in fish sampled from the Androscoggin, Kennebec, Penobscot, and Presumpscot Rivers.

Paints, household chemicals, and hundreds of other chemicals in daily use find their way to the estuary waters via sewage plants, storm sewers, and in regulated and nonregulated discharges. Chemical toilets on boats often use formaldehyde, a very toxic substance often emptied directly into estuary waters with sanitary waste. The EPA estimates more than 70,000 chemicals are in industrial use and an additional thousand more are introduced each year; few have been studied to assess their effect on human and aquatic life.

Toxic by-products of manufacturing often slip into regulated discharges by accident or on purpose. Storms wash a myriad of chemical traces into Maine estuaries. The synergistic effects of these substances, how they react and interact, is a mystery.

Biocides

Biocides include a broad range of chemicals designed to kill living organisms. Tributyltin (TBT), a biocide, is an antifouling compound used in boat bottom paint. Although the use of tributyltin is now restricted, it is still in use and accumulates with other heavy metals in the sediments of harbor areas and centers of boat building activity.

Commercial application and sales of pesticides is licensed and regulated by the Board of Pesticide Control (Maine Dept. of Agriculture, Food and Rural Resources). Residential use in Maine is unregulated.

Pesticides are biocides designed to kill plants and insects. Traces of pesticides are difficult to detect in the marine environment because the compounds are designed to break down into other substances in relatively short periods of time. The toxic effect of these secondary products is unknown. Large quantities of biocides are used on roadways, power line right-of-ways, golf courses, timber lands, apple orchards, blueberry fields and on other crops. Herbicide application on forest lands in Maine is the heaviest in the nation. Studies have found levels of pesticides in the groundwater of agricultural areas in Maine (Neil et al., 1989), but the presence of pesticides other than DDT in Maine estuarine environments, has not been investigated.

Temperature

People can alter the temperature of coastal waters and streams with discharges of heated wastewater. Maine Yankee Atomic Power Plant and coal-fired plants along the coast use estuary water for cooling turbines. Major changes in the landscape, such as paving over large areas or extensive clearcutting, will also increase the temperature of surface run-off with potentially damaging consequences for fish and other marine life.

When the estuary volume and flushing rate is high, the effect of warm water may be minimal. But even a small increase in water temperature can alter the ability of fish and shellfish to reproduce and may decrease oxygen levels in the water.

Sediments

Plowed fields, construction sites, road ditches, natural erosion, and clearcuts are the principal sources of sediments that wash into the estuary with each storm. Soil washing into tidal creeks and coastal waters blocks the light needed by aquatic plants and in sufficient quantities, smothers shellfish beds and bottom communities. Suspended sediments can damage gills and other sensitive fish

tissue. Dredging and bottom-dragging harvesting techniques also increase the turbidity of estuarine waters.

Marine Trash

Marine trash clutters miles of shoreline and threatens the health of estuarine animals. Fish, birds, and other wildlife ingest nonbiodegradable plastics or are entangled by them. Pieces of gillnet and ghost lobster traps keep on fishing for months or years after they disappear from the fisherman's care. Marine trash enters the environment from combined sewer outfalls, land run-off, rivers, streams, recreational boaters, shore side visitors, and fishermen. In Maine, commercial fishermen and recreational boaters are responsible for much of the marine debris found on our shores.

The 1989 Coast Week Cleanup in Maine covered 176 miles of shorefront and collected an average 102.6 pounds of debris per mile. (Data compiled by the Maine Coastal Program with assistance from the Center for Marine Conservation.)

Quality of Life and Coastal Culture

Development and pollution of estuary waters and uplands changes the lives of those who live and work along the coast. Pollution of estuarine waters and the subsequent decline in fisheries affects many coastal residents accustomed to making a living harvesting natural resources from coastal waters. Access to estuaries and other sections of the coast is becoming more restricted. Less than 10% of the Maine coast is in public ownership, yet more than 75% of the state's population lives within the coastal counties. A recent survey by the Maine State Planning Office revealed that almost 90% of clam and worm diggers cross private shorelands to get to flats. One-third of those surveyed had private property owners object to passage across their lands (Dawson, 1990).

Years ago, saltwater farms stretched down to the estuary edge. Many families owned a fish house and dock on the shore for convenient access to the water and as a place to store and repair fishing gear. In recent years, land values have soared and many residents cannot afford or choose not to maintain the waterfront farms and shore lots that have been in the family for generations. The sale and subdivison of family farms and waterfront lands leads to an increase in residential and road development and all the environmental problems associated with urban land use.

Chapter Three
Estuary Planning and Management

What is Estuary Management?

An estuary management program is designed to protect, sustain and improve the resources of an estuary watershed. Harbor management ordinances, land use and shoreland ordinances, and shellfish ordinances are among the regulatory tools used to manage estuaries. Volunteer water quality monitoring, community education, clam flat seeding and septic system pumping programs are a few examples of nonregulatory efforts underway in communities along the Maine coast. Ideally, estuary management involves all the communities bordering an estuary or within the same coastal watershed working together to define common goals and strategies to sustain the quality of coastal waters and other natural resources that they share.

The Need for Estuary Planning

As population and development pressures increase on the Maine coast, so does the need for protection and wise stewardship of estuaries and other coastal waters. Development concentrates at the edges of the coast, where water meets land in estuaries or other bays. State agencies have only limited authority to protect local resources by enforcing state environmental regulations. By thoughtful planning, towns can encourage economic development of estuaries that sustain diverse and abundant natural resources. Establishing priority uses in the estuaries will contribute to a healthy and clean environment.

Land use and resource planning offers local governments an opportunity to play an active role in directing future changes to their town rather than reacting to controversial developments crisis by crisis. Problems and issues involving land and resource development differ from area to area and are best handled by residents who understand the unique situation of their area and must live with the outcome.

Land use plans are an expression of community vision. The plans lay out scenarios describing the community in the future--where development should occur and businesses should locate, and which natural and cultural resources need to be protected. Planning provides an opportunity to anticipate and prevent problems such as permanent closure of productive clam flats, shorefront erosion, or an over-built coastline. **Prevention is always less expensive than remediation.**

Getting Started

Even if town government is not ready to address estuary planning on a large scale, estuary management efforts can be started by individuals or community groups with particular issues of concern--finding the sources of pollution causing a clam flat closure, improving anadromous fish runs, protecting a coastal marsh, or mapping estuary habitats.

The important thing is just to get started.

Estuary Planning & Comprehensive Planning

An estuary plan can be part of a town comprehensive plan and may lead to an ambitious regional effort involving many towns working together to balance the protection of natural resources within the coastal watershed with appropriate land use activities and water uses.

Maine communities are required by the Comprehensive and Land Use Regulation Act of 1988 to develop growth management programs that include a comprehensive plan and an implementation program to carry out the plan. Towns must include in their comprehensive plans, programs for the regional management of shared resources that extend beyond municipal borders, for example --estuaries and coastal watersheds. Most coastal towns will address estuary and embayment issues in sections of the comprehensive plan that cover water quality, marine resources, and other natural resource areas. In addition, discussions of estuarine issues and resources should be incorporated into sections concerning the local and regional economy, public access to the coast, and recreational opportunities.

Estuary planning should complement existing comprehensive plans and be included in future or updated comprehensive plans. Policies relating to water quality, natural resource conservation and land use within a plan can be used to develop local ordinances and programs that effectively manage estuarine resources and the resources of the coastal watershed.

Why are Comprehensive Plans Important?

Comprehensive plans are sources of information about the community, its lands and resources and projections for the future. Comprehensive plans provide the backup for legal challenges to ordinances enacted by the town. Just as federal laws must be consistent with the U.S. Constitution, so must town ordinances be backed by a document expressing the priorities and intentions of the residents.

Working Together

Estuaries are shared resources that require cooperative management. Large estuaries often span political boundaries, as do many other water resources such as freshwater lakes and groundwater aquifers. Estuary water quality, habitats and fisheries cannot be protected piecemeal.

If a town decides to protect a clam flat at one end of the estuary and another town encourages marina development across the water, the conservation action may be thwarted as oils and discharges from boat traffic pollute the flats or a shellfish closure prohibiting shellfish harvesting around the marina overlaps the conservation area. The comprehensive planning process provides an opportunity for towns to work together on issues relating to water quality and resource protection.

Home Rule & Responsibility of Local Government.

In Maine, as in many other New England states, all powers not expressly reserved by the state legislature are allowed to be exercised by municipal governments. This strong reliance on local control is called **'home rule'.**

Authority for designing, implementing, and enforcing most shoreland and other land use regulations resides with local government. Because of the tradition of home rule, towns have the prerogative to protect and manage resources within their jurisdiction.

Even if towns have different schedules for completion of an official Comprehensive Plan, they need to work together to plan the management of shared resources such as estuaries, ground water aquifers, and freshwater lakes. The regional nature of coastal watersheds requires communication and cooperation between towns as well as between state agencies with responsibilities in estuarine areas. In the lingo of planners, what is required for effective estuarine management is an "interlocal effort".

The Office of Comprehensive Planning (OCP) in the Maine Department of Community and Economic Development (MDECD) and local regional planning agencies provide assistance to towns developing comprehensive plans. (See Appendix for information.)

Planning Basics

The following reviews three stages in the development of an estuarine resource management plan and program. First, inventory the resources and identify the issues; then develop policies and recommendations for implementation measures; and finally, develop and enact ordinances, regulations, and programs that address the issues of concern and provide for long-term management of estuarine resources. Grass-roots public involvement and education programs are essential to ensure widespread support for the final plan and recommendations.

Inventories & Issue Identification

Inventories contain facts about natural resources, land use, and water use within the estuary watershed. **Collecting information is an ongoing process.** Inventories must be periodically revised with new data to reflect current trends and conditions so that policies and implementation measures can be updated. The inventory section of a plan also examines the needs and concerns of the community, and the types of measures needed to address those needs and concerns. Surveys and public meetings are useful tools to identify issues of concern and priorities of residents. Asking the right questions is necessary in order to obtain the desired information.

Windshield surveys are used to quickly identify nonpoint source pollution and general patterns of land use. Driving around, an observer can note areas of possible non-point source pollution by watching for recent construction, land-clearing activities, bare earth, or erosion gullies. Short surveys mailed to residents are useful to identify issues of concern and priorities for management.

Ask questions and note trends

Are clam flats closed due to bacterial pollution? Is water quality getting better or worse? Are there more applications for shoreland building permits than there used to be? Are the shorelands of the estuary "hardened" with parking lots, riprap, seawalls and other modifications?

Are there old dumps at the shores of the estuary or in nearby marshes and small wetlands? Where were the old mills and industries located, what did they produce and discard? Are the estuary shores and inlets littered with plastic trash and other debris? What has been the overall effect of incremental development along the estuary and in the estuary watershed?

Examples of Information to Collect and Map:

This list is not complete, but indicates the kind of information needed for an understanding of how an estuary fits into the local ecology and economy. (Addresses of sources are listed in Appendix A).

Estuary and estuary watershed unit boundaries.
Source: Maine Geological Survey (MGS).

Groundwater and surface water resources in the estuary watershed.
Sources: Topographic maps , MGS aquifer maps, regional planning agencies

MDEP Water Classification for surface waters in the estuary watershed.
Sources: Topographic maps, regional planning agencies, Maine Dept. of Environmental Protection (MDEP).

Major estuarine and marine habitats especially those related to commercially harvested marine resources including salt and fresh marshes, freshwater tidal habitat, flats, submerged aquatic vegetation (eelgrass meadows), migratory fish streams, shellfish and marine worm beds, aquaculture lease sites.
Sources: Maine Coastal Marine Environment maps available from MGS; shellfish maps available from Maine Dept. of Marine Resources (MDMR) area biologists.

Major land uses in the estuary watershed--farmland, conservation, tree growth, urban, rural residential. Shoreland zones and other existing zoning districts.
Sources: Regional planning agencies, soil and water conservation districts offices, tax maps.

Areas with significant botanical, archeological, wildlife, geological, or scenic resources. High value deer yards and wintering areas; waterfowl, shorebird, and wading bird nesting and feeding areas; spawning and nursery areas for Atlantic salmon and Bald Eagle nesting areas.
Sources: Heritage Program (Maine Dept. of Economic and Community Development), Critical Area Program (Maine State Planning Office), Maine Dept. of Inland Fish and Wildlife (MIFW) area biologists, surveys.

Locations of present and past sources of pollution to estuarine waters including licensed discharges.
Source: The Water Quality Control Bureau (MDEP) will provide computer printout of discharges by town and discharge license limits--the amount and type of pollutant allowed to be discharged.

Research the location of historical industrial sites and land use, including the location of forgotten underground fuel tanks, town dumps or industrial dumps.
Sources: Historical society records, town libraries, old insurance maps.

Non-point source pollution i.e., malfunctioning septic systems, combined sewer overflows, stormwater drainage outfalls, road drainage culverts and ditches, clearcut areas, livestock yards.
Sources: Town road maps and sewer district plans, local water quality groups, MDMR area biologists.

Coastal hazard areas, sand dunes, and flood plains.
Sources: County emergency management agencies, MGS (sand dune maps), MDECD.

Existing and suitable areas for water dependent activities including boatbuilding, harbors, fish buying stations, lobster holding areas, moorings, weirs.
Sources: Coastal water dependent use maps are available from regional planning agencies or the Office of Comprehensive Planning (MDECD).

Sites ideal for shellfish or finfish aquaculture.
Sources: MDMR area biologists, Maine Aquaculture Association.

Traditional paths to the shore, public access sites, boat ramps.
Sources: Old maps, public surveys, tax maps.

Underground petroleum storage tanks, waterfront gas tanks and oil distribution facilities.
Sources: A list can be obtained from the Office of Oil and Hazardous Materials (MDEP) or county emergency management agencies.

Estuary profiles are available for nineteen Maine estuaries. The profiles are brief descriptions of selected estuaries. Maps are available for five estuaries. Estuary profiles and maps are available from the Maine State Planning Office, regional planning agencies, and University of Maine Cooperative Extension offices.

Estuarine Management Issues

Each estuary along the Maine coast is unique; issues of concern differ between areas. The following are only a few of the issues to be considered when designing an estuary management plan.

Aquaculture

When planning for sustainable economic development, towns should identify and protect existing and potential aquaculture development sites. Precautions must be taken to ensure that aquaculture operations are sited to minimize the effect on water quality. Aquaculture enterprises can provide year-round employment opportunities, supplement incomes of traditional fishermen, and contribute to the local economy. Proposed aquaculture development often concerns harvesters fishing wild stock near the proposed lease site and riparian landowners. Plans to protect existing and potential aquaculture sites should address the concerns of all users of the estuary.

Waterfront Development

Large-scale waterfront development projects are often controversial in Maine as communities struggle to define and retain their identity. Conversion of shorefront business properties to condominiums or recreational marinas is often perceived as a threat to traditional fishing-related uses of the waterfront. Harbor management plans and ordinances, which regulate water use pertaining to mooring and navigation channels, and shoreland zoning, which designates the type of land development within 250 ft. of tidal water, are key tools in managing urban waterfronts.

Coastal Hazards and Sea Level Rise

Unstable shore environments such as flood zones, bluffs and sand dune areas need additional restrictions on alteration and construction within buffer zones that exceed the minimum requirements of state shoreland zoning and flood plain management regulations. A slow rise in sea level caused by global changes in climate will alter the shape of the coast in the near future. Long-term shoreland planning must allow room for marshes, dune fields and other coastal habitats to migrate inland as sea level rises. Setbacks for homes, businesses, and especially septic systems and wells should reflect projected sea level rise and natural rates of shore erosion.

Clam Flat Closures

Extensive closures of areas to the harvest of shellfish because of bacterial pollution may cause hardship in small coastal communities especially when many residents depend on digging for all or part of their income. Bacterial pollution in Maine estuaries generally comes from a combination of sources such as septic systems, municpal sewage treatment plants, stormwater run-off, flocks of waterfowl, or livestock yards. Pollution from each of these sources can be prevented by a combination of regulations, inspections, public information, and publically funded improvements.

Public Access

The State of Maine has a unique tradition of public access across private land. Fishermen and coastal residents have long enjoyed informal access to the coast and estuaries for fishing or recreation. Fishermen often haul boats and store gear out of the reach of tide on private beaches. As the coast becomes more developed, free and open access to the coast is becoming limited. Paths down to the shore and shortcuts along the coves that people have used for years are often blocked off with 'No Trespassing' signs soon after the property is sold. Conservation easements, shorefront purchases and legal right-of-ways are tools towns can use to preserve traditional access to coastal waters.

Who Owns the Estuary?

The people of Maine own the lands below low tide and the estuary waters. In areas of extensive intertidal flats, private ownership extends for a distance of 1650 feet from the high water mark before public ownership begins. The Bureau of Public Lands in the Maine Department of Conservation and the Maine Department of Marine Resources manages and grants leases on submerged lands. In the intertidal zone, between the high and low water mark, the public has certain rights even if the shoreland is privately owned.

These rights, established by the Colonial Ordinance enacted by the Massachusetts Bay Colony in the 1640s, include fishing, fowling and navigation as well as skating, salt ice cutting, mooring boats and worm and shellfish digging. The use of private shorelands for sunbathing and other recreation was possibly limited by the 1987 Moody Beach decision which upheld the right of private shorefront owners along a beach in Wells, Maine to restrict access by the public.

Policy Development

Policies are based on analysis of the information gathered during the inventory and issue identification effort. Policies are clear, specific, and enforceable statements that direct future planning decisions. Policies developed for Comprehensive Plans must be consistent with the nine coastal management policies and ten growth management goals of the State of Maine. The policy section of a plan usually includes overlay maps that specify the locations of various land and water use categories--for instance the location of conservation areas, high density development areas, water dependent use zones, shoreland zoning areas, and MDEP water classifications.

Policies are specific statements related to a general goal. For instance, if the goal is "to protect the marine resources", the policy may read:"The Town of _____ will revise its shoreland zoning ordinance to establish a new resource protection district around the western side of _____Estuary". Policies recommend implementation measures which are described in detail in an implementation program.

The following topics are included in the coastal policies of the State of Maine are within the scope of estuary planning:

1. Port and Harbor Development
2. Marine Resource Management
3. Shoreline Management and Access
4. Hazard Area Development
5. State and Local Cooperative Management
6. Scenic and Natural Areas Protection
7. Recreation and Tourism
8. Water Quality
9. Air Quality

Implementing Estuary Management

Maine towns have limited direct jurisdiction over estuarine waters, but are able to regulate boating and shellfish harvesting activities. By preparing harbor management and comprehensive plans that address uses of the estuary, towns can influence the decisions of regulatory agencies at the state and federal level. The public may comment on applications for state leases of submerged lands, dredging projects, wetland alterations, discharge licenses and other activities that are regulated by the state. Organized public comment can directly affect these activities that are outside the direct jurisdiction of towns.

The water classification designations described in Chapter Two can be used by towns to regulate permitted uses. Towns and residents can influence the classification of surface waters during the public hearing and review period mandated every three years. For instance, an upgrade of a section of an estuary from Class SB to Class SA waters would require the removal of all discharges and prohibit future dredging projects. Upgrading Class SC waters to Class SB would require discharges to meet higher standards and eventually result in improved water quality.

Most importantly, towns can directly influence coastal water use and quality by managing adjacent land use. Many users of estuary waters require shore access or water quality that permits certain uses of the waters and submerged lands. These water dependent uses include, but are not limited to, shellfish harvest, aquaculture, lobster holding, swimming, recreational boating, and fishing. By implementing zoning and other measures that direct land development along the shore and in the coastal watershed, towns can control the use of estuary waters and uplands within their jurisdiction.

Implementation Measures

Implementation measures are the ordinances and programs used to carry out the policy decisions made in a comprehensive plan. For years, Maine communities have used many tools to manage estuary resources. The tools include regulatory measures--zoning, subdivision, shellfish, and harbor ordinances and regulations, and nonregulatory programs--citizen water monitoring programs, coastal cleanups, stormwater management projects, capital improvements to sewage treatment plants, shellfish seeding efforts, and removal of obstructions to fish migration.

Every community and region will find that a certain combination of approaches best conserves estuarine resources while allowing sustainable growth and development.

Regulatory Measures

Zoning Ordinances

Zoning controls development by establishing standards such as minimum lot size or setbacks. Maine towns use a variety of zoning techniques to regulate development.

Shoreland Zoning--Shoreland zoning is a state-wide program requiring local regulation of development within a minimum of 250 feet of tidal waters, Great Ponds, coastal and freshwater wetlands, and rivers and within 75 feet of certain streams. Municipal governments must adopt and enforce local shoreland zoning ordinances that meet or exceed the minimum requirements issued by the Department of Environmental Protection.

* Increase minimum setbacks established by the State in areas of natural hazards (sand dunes, steep banks, and bluffs), and flood plains. **Purpose: To protect property and reduce erosion.**

* Establish conservation zones or resource protection districts along the shore and uplands bordering productive shellfish beds, spawning areas, eelgrass beds, tidal creeks, wetlands and other important estuarine habitats. **Purpose: To protect and conserve water quality and natural resources.**

> The Town of Yarmouth established a resource protection district (River Corridor) regulating filling activities and uses. The district includes the tidal marsh wetlands and areas within the 100-year floodplain of the Royal River, Cousins River and Pratts Brook or lands within 100 horizontal feet of the normal high water mark. This district is part of Yarmouth's shoreland zoning ordinance.

* Zone the waterfront to reserve area for water dependent uses. **Purpose: To protect marine and fishing related activities from competing and incompatible uses.** Guidelines for Commercial Fishing/ Maritime Use Zones are available from the Maine Department of Environmental Protection and the Office of Comprehensive Planning.

Town-wide Zoning-- All coastal Maine communities have in place minimum lot size and subdivision ordinances or rely on the minimums specified in the State Plumbing Code that apply to all areas within the town. Land use ordinances provide an opportunity to enact measures that protect water quality within the coastal watershed and by extension, the estuary.

* Direct planning boards or conservation commissions to review subdivision plans for waste disposal, road drainage, and effect on coastal wetlands and surface waters. **Purpose: To encourage impact assessment beyond the immediate confines of the project and protect water quality.**

* Prohibit the direct channeling of surface water runoff into adjacent water bodies and require that design and construction standards be

Build-out studies are useful exercises.
When designing ordinances, assume that eventually the area will be built up to the limits of existing regulations.

For example, if an area is zoned two acres minimum, imagine a probable future where the land will be subdivided entirely into two acre parcels. Incentives for protection of agricultural lands, conservation easements or clustered housing with open space may need to be included to achieve the ideal landscape envisioned. Regional planning councils and the Office of Comprehensive Planning can assist with build-out studies.

met for storm drainage. **Purpose: To protect water quality and reduce nonpoint source pollution.**

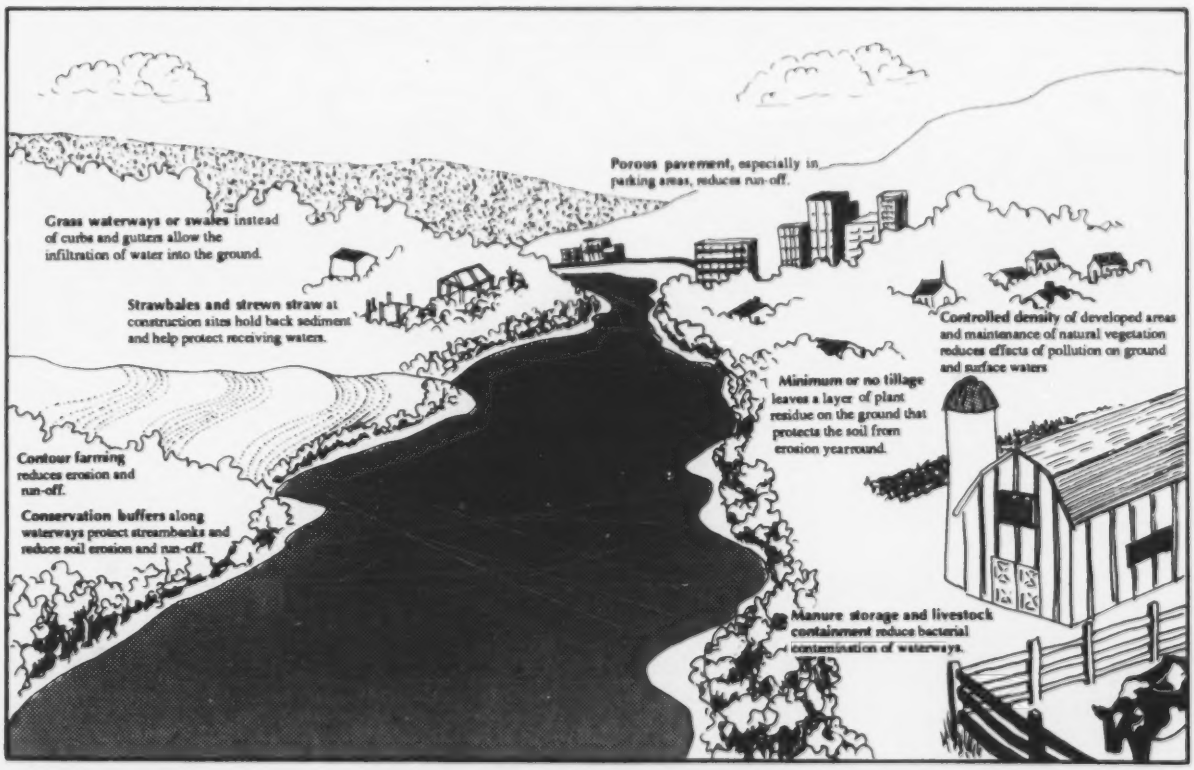
* Require developers to provide information about and to assess the local environmental impact of a proposed development beyond the requirement of the state subdivision law. **Purpose: To encourage developers to assess the environmental values affected by the project and use best management practices to reduce impact on the environment.**

Overlay Zones--Overlay zones are mapped zones that apply regulations or requirements in addition to those of one or more underlying zoning districts. Overlay zones are a flexible tool that can be used to promote uses by imposing additional criteria without changing the existing permitted uses, densities and specifics of the base zones.

> The City of Portland created a waterfront overlay district to promote and protect activities related to the fishing industry. The Town of York has a watershed protection overlay zone that establishes permitted and prohibited uses and performance standards for development.

Best Management Practices

Best Management Practices (BMPS) are design or construction standards that are recommended or required by ordinances or regulations to minimize the impact of development on the environment.


Porous pavement, especially in parking areas, reduces run-off.
Grass waterways or swales instead of curbs and gutters allow the infiltration of water into the ground.
Strawbales and strewn straw at construction sites hold back sediment and help protect receiving waters.
Controlled density of developed areas and maintenance of natural vegetation reduces effects of pollution on ground and surface waters
Minimum or no tillage leaves a layer of plant residue on the ground that protects the soil from erosion yearround.
Contour farming reduces erosion and run-off.
Conservation buffers along waterways protect streambanks and reduce soil erosion and run-off.
Manure storage and livestock containment reduce bacterial contamination of waterways.

Examples of Best Management Practices

42 BEST COPY AVAILABLE

Sources for model ordinances (listed in Appendix)

Harbor & Land Use Ordinances
MDECD (Office of Comprehensive Planning) and regional planning agencies.

Shoreland Ordinances
MDEP (Land Bureau, Shoreland Zoning Coordinator) and Maine Association of Conservation Commissions.

Watershed Protection & BMP's
MDEP (Water Bureau, Nonpoint Source Pollution Program) and local Soil and Water Conservation Districts.

Shellfish Ordinances
MDMR Shellfish Program.

General
How to Prepare a Land Use Ordinance: A Manual for Local Officials (1990), available from the Office of Comprehensive Planning.

Harbor Management Ordinances

Intensified use in and around harbors has led to the need for harbor management plans and ordinances. Assisted by the Maine Department of Economic and Community Development, several Maine towns have developed plans to coordinate use of their harbors. Integration of harbor plans into estuary plans is essential to evaluate the impact of harbor development on the natural resources of the entire estuary.

Health Regulations

Health regulations can be used to reduce bacterial pollution of estuary waters.

*Require inspection of septic system before property transfer and upgrade if neccesary. **Purpose: To upgrade in-ground septic systems.**

*Create a **sanitary wastewater management district**. Put all the septic systems within a specified district on a regular maintenance and inspection schedule. **Purpose: To ensure that septic systems are maintained and provide maintence services at an affordable cost.**

Shellfish Programs & Ordinances

At least forty-three towns in Maine have shellfish conservation ordinances which regulate the licensing of clam diggers and management of shellfish flats. Among the measures towns have taken to protect their clam flats are designation of conservation areas, limiting the number of licenses overall and limiting the number of licenses granted to non-resident diggers, and seeding of clam flats. Regional biologists (MDMR) assist towns and shellfish conservation commissions with ordinances and conservation programs. The Brunswick Shellfish Management Program is a model program of regionally based management of a shared natural resource. Reciprocity agreements between the towns of Harpswell, West Bath, and Phippsburg coordinate the opening and closing of shellfish flats to prevent overharvesting of one area.

Migratory Fish Regulations

Twenty-eight towns manage alewife fisheries. The towns usually grant contracts to private parties to harvest the alewife run. Limits are set by the state and towns regarding the season and hours of harvesting operations.

Nonregulatory Measures

Marine Water Quality Task Force

A marine water quality task force brings together all the local agencies, municipal officials and concerned citizens to coordinate local water quality improvement efforts and promote understanding of marine quality issues. In the Machias River area, a task force coordinated by the county emergency management office is examining the water quality problems of the Machias River estuary and inner Cobscook Bay.

Water Quality Testing Program

The Maine Department of Marine Resources (MDMR) and the Maine Department of Environmental Protection (MDEP) are responsible for testing estuarine waters for pollution. State agencies lack the resources to cover the approximately 3,500 miles of Maine coastline. Volunteers can contribute to the collection of water quality information by gathering and testing water samples and investigating the sources of pollution. Citizens along the Damariscotta and St. George Rivers monitor water quality with the assistance of the University of Maine Cooperative Extension Program and the MDMR Shellfish Program.

Technical training manuals and assistance for volunteer water quality monitoring groups are available from local offices of the University of Maine Cooperative Extension.

Shore Steward Program

Estuary residents can form a Shore Steward group to watch over a stretch of shoreline. The Shore Steward Program is an effort similar to neighborhood watch or Adopt-A-Stream programs, but is focused on caretaking stretches of coastal shoreline.

For more information write:
Shore Steward Program, State Planning Office, State House Station #38, Augusta, ME 04333.

Household Toxic Material Reduction and Collection Program

Although the amount of lawn fertilizers and herbicides, garden pesticides and household chemicals used by an individual may be minor, the total amount used by all the individuals within a coastal watershed, in addition to roadside and utility right-of-way herbicide spraying, is significant. Even trace amounts of pesticides are toxic to soft-shelled clams. Herbicides may destroy aquatic vegetation and fertilizers add excessive amounts of nutrients to estuarine waters. Distribution of information to homeowners on alternatives to toxic chemicals can reduce their use in the coastal watershed. Periodic municipal collections of household toxic chemicals will prevent improper disposal and possible contamination of water quality. Contact local University of Maine Cooperative Extension offices for assistance in establishing a community collection program.

Land Acquisition & Conservation

For property tax assistance information, write: Maine Residents Property Tax Program, Bureau of Taxation, State Office Building, Augusta, Me 04333, or call 1-800-452-1983.

Faced with soaring property taxes some shorefront owners opt to subdivide or sell their land. Towns and local conservation groups and land trusts can work together to provide information on alternatives to development or sale of shorefront property. The Maine Residents Property Tax Program offers property tax relief to eligible residents. Donations of conservation easements, tree growth designation and sale of development rights are also options available to owners seeking to reduce property taxes or preserve the natural character of their land.

For information on creative approaches to conserve land contact: Maine Coast Heritage Trust, The Nature Conservency, and local land trusts.

Some communities have researched historic rights-of-way and rediscovered areas that allow public access to coastal waters. Waterfront Action Grants (administered by the Office of Comprehensive Planning) and other grant programs have been used by towns to purchase shorefront and other lands.

In response to development pressure, voters on Nantucket Island, Massachuesetts authorized in 1983, a two percent land transfer tax to fund a land bank established to purchase open space for use by island residents.

Marine Resource Conservation & Improvement Programs

Often regulation of shellfish and fish harvesting is not enough to protect the abundance of estuarine resources. Identification and protection of significant estuary habitats, public outreach efforts, and investigations of the sources of pollution to coastal waters are all important for a successful natural resource program.

For information on hatchery projects contact: Hancock Co. Cooperative Extension, Boggy Brook Rd. RFD 5, Ellsworth, ME 04605 for Shore Harvester News newsletter. Regional MDMR biologists will assist with resource inventories and conservation plans.

Several towns in Maine have implemented reseeding programs to improve local clam flats. Near Jonesboro a group of ten towns cooperatively operate a regional clam hatchery. Many communities are improving fishladders and removing obstructions that block passage by migratory fish to inland waters.

How To Keep the Ball Rolling.....

Long-term estuary planning must be integrated into existing efforts and must enjoy the general support of the community. Fish, shellfish, conservation, comprehensive planning, and harbor committees all contribute to management of the estuary and the coastal watershed.

Institutional Arrangements

Organizing estuary conservation efforts and keeping those efforts alive after completion of a comprehensive plan provides a true challenge to community leaders. Meshing estuary watershed conservation efforts with existing programs or institutions is one way to ensure continuity over time. Conservation commissions and soil and water conservation districts are examples of existing groups whose purpose is to conserve and manage natural resources. Involvement in estuarine and coastal watershed issues is a natural extension of their original mandates.

Conservation Commissions

Conservation commissions are municipal boards created by the local government to identify and conserve the natural resources within a town. A conservation commission can review and coordinate town response to state permit applications, such as wetland alteration and dredging proposals, water classification hearings, or discharge permits, and can provide assistance to local planning boards. Usually conservation commissions serve in an advisory role to town government; they can be granted more powers at the discretion of the municipality. A local conservation commission can play an important role in organizing public outreach programs on estuarine resource and water quality issues and undertaking a resource inventory of the estuary watershed.

At one time there were over 200 towns with conservation commissions in Maine, but many disbanded over the years. More than 100 conservation commissions are still active in Maine and several communities are planning to revive their old commissions. The Maine Association of Conservation Commissions (MACC) is a nonprofit organization dedicated to providing support and information to local commissions in Maine.

To find out more about conservation commissions contact the Maine Association of Conservation Commissions, P.O. Box 222, Belfast, ME 04915.

Soil and Water Conservation Districts

For more information on projects and technical assistance contact the district or State Soil and Water Conservation Commission, State House Station #28, Augusta, Maine 04333.

Sixteen Soil and Water Conservation Districts (SWCD) in Maine are very active in water quality protection and soil conservation. The districts are involved with soil mapping, floodplain studies, small watershed protection efforts, erosion and non-point source pollution control projects, septic and sewage sludge disposal, the small watershed program, and other resource protection and conservation programs. The districts also review resource alteration permits submitted to state agencies and make recommendations. Local SWCDs are assisted by the State Soil and Water Conservation Commission which is part of the Maine Department of Agriculture.

Coastal Watershed Districts

In early 1990, an act allowing for the creation of Coastal Watershed Districts was passed by the Maine legislature. This legislation was an extension of the law that allows the creation of watershed districts to protect inland lakes. The purpose of coastal watershed districts is **"to protect, restore and maintain water quality and aquatic resources of coastal harbors, bays, estuaries and other coastal waters and to manage and conserve the land and water resources of coastal watersheds within the jurisdiction of these districts."**

For more information on coastal watershed districts contact the Maine Association of Conservation Commissions.

The responsibilities of coastal watershed districts include initiating and coordinating research on aquatic resources and coastal environments; planning coastal restoration projects to improve water quality and to enhance aquatic resources within the district; working to coordinate ordinances and regulation within the watershed district; and adoption and implementation of coastal protection, management and restoration plans.

A watershed approach to management of coastal resources is an approach advocated by coastal communities around the country. The creation of coastal watershed districts is an opportunity for Maine communities to regionally manage coastal land and water resources. The revised marine resource plan of the Town of Brunswick recommends the formation of a coastal watershed district to address water quality problems in Maquoit Bay and Middle Bay.

Historically, Maine communities have been reluctant to form regional watershed districts. Although many Maine communities have discussed creating lake watershed districts, only one group of communities has formally agreed to cooperatively manage their water resources. The Cobbossee Watershed District, organized in 1971, is a joint effort by the City of Gardiner, and towns of Litchfield, Mt. Vernon, Manchester, Monmouth, Readfield, Richmond, Wayne and Winthrop; to protect and restore 28 lakes within the watershed.

Citizen Involvement and Information

Successful estuary planning and management requires grass root public involvement. All the major users of the estuary should be invited to participate. This includes, but is not limited to--clammers, wormers, aquaculturists, municipal sewer plant operators, conservation groups, landowners, school groups, industry representatives, and other local business people. Public education on the impact of common activities on estuarine ecology is often more effective than regulation. For instance, boat pumpout facilities are often underutilized by boaters because they are less convenient than pumping sewage overboard. Enforcement is almost impossible; education on the effect of overboard discharge is the often the best way to promote compliance.

Enforcement in the Estuary

The local Code Enforcement Officer is responsible for enforcing town ordinances including shoreland zoning. By sharing the same Code Enforcement Officer, towns within a watershed can promote fair enforcement of each town's regulations and ordinances. The harbor master in an estuary has authority to assign moorings, direct boat traffic, enforce boat discharge regulations, keep navigation channels clear and control other activities affecting harbor waters.

For information on the Code Enforcement Officer Training Program or a copy of 'A Handbook for Municipal Officials on Interlocal Code Enforcement,' contact: MDECD, Office of Comprehensive Planning, Augusta, Maine 04333.

Marine Patrol (MDMR) and local shellfish wardens enforce shellfish and fish regulations on tidewater, and game wardens (MIFW) enforce fish and game rules on fresh water and uplands. Maine towns rarely fine violators of local ordinances; instead they usually require correction. Enforcement ultimately depends on citizen cooperation. People who live or work on an estuary are usually the first to know of a water quality problem or shoreland zoning violation. Concerns should be reported to the town office and staff need to know who to contact next.

The Town Of Brunswick- A Case Study

Several years ago, a group of Brunswick residents became concerned that the clam resource of Brunswick tidal flats were threatened by pollution from land run-off. The residents formed the Bays Planning Committee and set out to revise the marine resource section of their comprehensive plan in order to protect the town clamming industry valued at over two million dollars a year in harvested value.

In June 1989, the Town of Brunswick completed "The Maquoit & Middle Bays Comprehensive Plan Revision". To date, this document is the best example of a local plan that provides for the longterm protection of estuarine and marine resources. The plan suggests bold and innovative programs--the creation of sanitary wastewater management districts and a watershed protection district, specific recommendations to reduce non-point source pollution by limiting the percentage of a lot that can be covered with an impermeable surface, regulating shoreside fuel facilities and developing a Toxic Material Disposal Plan. With these measures the Town hopes to protect its soft-shell clam industry from land-based pollution.

Maquoit and Middle Bays Comprehensive Plan Revision by Christopher Heinig of Intertide Corporation, South Harpswell, Maine, June 16, 1989 for The Town of Brunswick Bays Planning Committee.

What Planning Can't Do

Not all problems can be solved by planning and management at the municipal or local level. Individual actions will make the difference. Boat owners need to dispose of trash properly and eliminate or reduce the use of chlorine in heads and for boat maintenance. Clam diggers and other harvesters must respect conservation closures and aquaculture leases. Property owners and developers need to be aware of the impact of their activities on the surrounding land and waterscape and investigate best management practices even if not required to do so by local regulations. Fundamental changes in the way individuals do things will have the most profound and long lasting effect on estuaries and the resources we treasure.

Recommended Reading For More Information

Coastal Management Techniques, A Handbook for Local Officials, prepared by Land & Water Associates and Maine Tomorrow, Hallowell, ME, Maine Dept. of Economic and Community Development, Augusta, ME, October 1988.

This excellent handbook discusses issues associated with devel opment along the coast and provides examples and explanations of management techniques used by Maine communities Available from MDECD, Office of Comprehensive Planning.

Financing Marine and Estuarine Programs: A Guide to Resource, Environmental Protection Agency, Washington DC, September 1988.

A primer focusing on accessing revenues, managing the flow of funds and buiding institutions to oversee financial planning and management with case studies of creative financing by commu nities around the country. Available from EPA, Office of Marine and Estuarine Protection, Washington D.C. 20460.

Guidelines for Maine's Growth Management Program, MDECD, Office of Comprehensive Planning, Augusta, ME, December 1988.

Available from MDECD, Office of Comprehensive Planning.

Managing Maine's Harbors and Waterfronts, Maine State Planning Office and Maine Department of Economic & Community Development, Office of Comprehensive Planning, Augusta, ME, November 1989.

Background materials on major water quality issues and natural resources including toxic and nutrient pollution, historical pollution, dredging, and writing harbor ordinances. Available from regional planning agencies and MDECD, Office of Comprehensive Planning.

Managing the Shoreline for Water Dependent Uses, A Handbook of Legal Tools, prepared for the New England/ New York Coastal Zone Task Force by the Marine Law Institute, University of Maine School of Law, Portland, ME, December 1988.

A technical handbook describing legal tools used by New England communities including many in Maine, to manage land and water use along the coast. Available from the Maine State Planning Office.

Natural Resources Handbook, A Planning Tool for Maine Communities, prepared for the Maine State Planning Office, by the Maine Association of Conservation Commisssions, July 1987.

A handbook explaining how to conduct a natural resource and land use inventory, mapping the information and interpreting the results. Available from: Maine Association of Conservation Commissions or MDECD.

Watershed: An Action Guide to Improving Maine Waters , Maine State Planning Office, Maine Department of Environmental Protection, and University of Maine Cooperative Extension, Augusta, ME, April 1990.

This guide describes actions an **individual** can do to improve water quality and reduce nonpoint source pollution. Available from local University of Maine Cooperative Extension offices.

Snowy Egret
(Egretta thula)

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Fefer, S.I. and P.A. Schettig (editors) 1980. An Ecological Characterization of Coastal Maine (North and East of Cape Elizabeth), U.S. Fish and Wildlife Service, Northeast Region, Newton Corner, MA. FWS/OBS-80/29.

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Larsen, P.F., D.F. Gadbois, A.C. Johnson and L.F. Doggett 1983. Distribution of polycyclic hydrocarbons in the surficial sediments of Casco Bay, Maine, Bulletin of Environmental Contamination and Toxicology 30: 530-535.

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North Carolina Department of Natural Resources and Community Development 1986. A Guide to Protecting Coastal Waters Through Local Planning, Division of Coastal Management, North Carolina Dept. of Natural Resources and Community Development , Raleigh, NC.

Pritchard, D.W., 1967. What is an Estuary?: Physical viewpoint, *in* Lauff, G. H., ed., *Estuaries*. Am. Assoc. Adv. Sci., Washington, DC, p.3-5.

Short, F.T., 1988. "Eelgrass Distribution and Status in the Maquoit Bay and Middle Bay Areas of Brunswick, ME", (unpublished).

Appendix
Sources for Information

The agencies and organizations listed here are a partial listing of those that can provide information and assistance with estuary planning and resource management efforts.

For further information consult **'Environmental Resources of Maine'**, a directory available from the Maine Department of Environmental Protection (call 289-2811 for copies) or **'Coast-Links, A Resource Guide to Maine's Coastal Organizations'**, a publication available from the Coastal Program (call 289-3261 for copies).

Cooperative Extension Offices

University of Maine Cooperative Extension (UMCE)
9 Coburn Hall, Orono, ME 04469 (581-3181)
Androscoggin/Sagadahoc Counties Cooperative Extension
277 Minot Ave. Auburn, ME 04210 (786-0376)
Cumberland County Cooperative Extension
96 Falmouth St., Portland, ME 04103 (780-4205)
Hancock County Cooperative Extension
Boggy Brook Rd., RFD 5, Ellsworth, ME 04605 (667-8212)
Kennebec County Cooperative Extension
290 Eastern Ave., Augusta, ME 04330 (622-7546)
Knox/Lincoln Counties Cooperative Extension
375 Main St., Rockland, ME 04841 (594-2104)
Penobscot County Cooperative Extension
Court House Annex, 105 Hammond St., Bangor, ME 04401 (942-7396)
Waldo County Cooperative Extension
RFD , Box 641, Belfast, ME 04915 (342-5971)
Washington County Cooperative Extension
11 Water St., Machias, ME 04654 (255-3345)
York County Cooperative Extension
P.O. Box 347, Alfred, ME 04002 (324-2814)

Environmental Organizations

Maine Aquaculture Association
P.O. Box 535, Damariscotta, ME 04543 (563-8168)
Maine Association of Conservation Commissions
P.O. Box 222, Belfast, ME 04915 (338-5538)
Maine Audubon Society
Gilsland Farm, 118 U.S. Route 1, Falmouth, ME 04105 (781-2330)
Maine Coast Heritage Trust
167 Park Row, Brunswick, ME 04011 (729-7366)
Natural Resources Council of Maine
271 State St., Augusta, ME 04330 (622-3101)
The Nature Conservancy
P.O. Box 338, 122 Maine St.
Topsham, ME 04086 (729-5181)

Regional Planning Councils

Capital Coastal Council of Governments
89 Western Ave., Augusta, ME 04330 (622-7146)
Eastern Mid-Coast Planning Commission
9 Water St., Rockland, ME 04841 (594-2299)
Greater Portland Council of Governments
233 Oxford St., Portland, ME 04101 (774-9891)
Hancock County Planning Commission
RFD 4, Box 22, Ellsworth, ME 04605 (667-7131)
Lincoln County Municipal Resource & Planning Office
Lincoln County Courthouse, P.O. Box 249, Wiscasset, ME 04578 (882-6358)
Penobscot Valley Council of Governments
1 Cumberland Place, Suite 300, P.O. Box 2579, Bangor, ME 04401 (942-6389)
Southern Maine Regional Planning Commission
Box Q, 255 Maine Street, Sanford, ME 04073 (324-2952)
Washington County Regional Planning Commission
63 Main St. Machias, ME 04654 (255-8686)

Soil and Water Conservation Districts

Cumberland County SWCD
1A Karen Dr., Westbrook, ME 04092 (871-9247)
Hancock County SWCD
41 Main St., Ellsworth, ME 04605 (667-8663)
Kennebec County SWCD
Federal Bldg. Rm. 408-C, Western Ave., Augusta, ME 04330 (622-8250)
Knox-Lincoln Counties SWCD
RR1, Box 15, Waldoboro, ME 04572 (832-4292)
Penobscot County SWCD
970 Illinois Ave., Bangor, ME 04401 (941-8973)
Waldo County SWCD
69 Northport Ave., Belfast, ME 04915 (338-2320)
Washington County SWCD
49 Court St., P.O. Box 121, Machias, ME 04654 (255-4659)
York County SWCD
160 Cottage St., Sanford, ME 04073 (324-7015)

State Agencies

Maine Department of Agriculture, Food and Rural Resources
(Soil and Water Conservation Commission)
Deering Building, AMHI Complex, Station 28, Augusta, ME 04333 (289-3871)

Maine Department of Conservation
(Bureau of Public Lands, Land Use Regulation Commission, Maine Geological Survey)
Harlow Building, AMHI Complex, Station 22, Augusta, ME 04333 (289-4900)

Maine Department of Economic and Community Development
(Office of Comprehensive Land Use Planning, Heritage Program)
Capitol Center, 219 Capitol St., Station 130, Augusta, ME 04333 (289-6800)

Maine Department of Environmental Protection
(Bureau of Land Quality Control, Bureau of Water Quality Control, Bureau of Oil and Hazardous Materials Control)
Ray Building, AMHI Complex, Station 17, Augusta ME 04333 (289-7688)
Regional Offices:
South Portland: DEP 312 Canco Rd.,So. Portland, ME 04103 (879-6300)
Bangor: DEP 106 Hogan Road, Bangor, ME 04401 (941-4570)
Presque Isle: DEP 1235 Central Parkway Dr., Presque Isle, ME 04769 (764-2044)

Maine Department of Inland Fisheries and Wildlife
284 State St. Station 41, Augusta, ME 04333 (289-3371)
Regional Offices:
Region A (Kittery to Phippsburg), RR1, 328 Shaker Rd., Gray, ME 04039 (289-3849, 1-800-322-1333) (Phil Bozenhard)
Region B (Georgetown to Searsport), 8 Federal St., Augusta, ME 04330 (289-2536, 1-800-322-3606) (Eugene Dumont)
Region C (Penobscot to Eastport), 68 Water St., Machias, ME 04654 (255-3266) (Tom Schaeffer)

Maine Department of Marine Resources
Stevens Complex (Hallowell) Station 21, Augusta, ME 04333 (289-2291)
Regional Biologists:
(New Hampshire Border to Kennebec River) Box 12, Dixon Rd., Ogunquit, ME, 03907 (646-3322) (Brad Sterl)
(Kennebec River to Union River) East Shore Rd., Brigham's Cove, West Bath, ME 04530 (443-6559) (Donald Card)
(Union River to Canadian Border) RR1 Box 172, Gouldsboro, ME 04607 (422-3167) (Jay McGowan) & P.O. Box 37, East Machias, ME 04630 (David Clifford)

Maine State Planning Office
(Critical Areas Program, Ecological Reserves, Land for Maine's Future, Maine Coastal Program, Shore Stewards)
184 State St., Station 38, Augusta, ME (289-3261)

Resource Conservation and Development Areas

Downeast RC&D Area
P.O. Box 210, Cherryfield, ME 04622 (546-2368)

Threshold to Maine RC&D Area
1A Karen Dr., Westbrook, ME 04092 (871-9248)

Time and Tide RC&D District
US Route 1, Box 12, Waldoboro, ME 04572 (832-5348)